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United States Coast Guard

Passenger Carrying Submersibles:
System Safety Analysis

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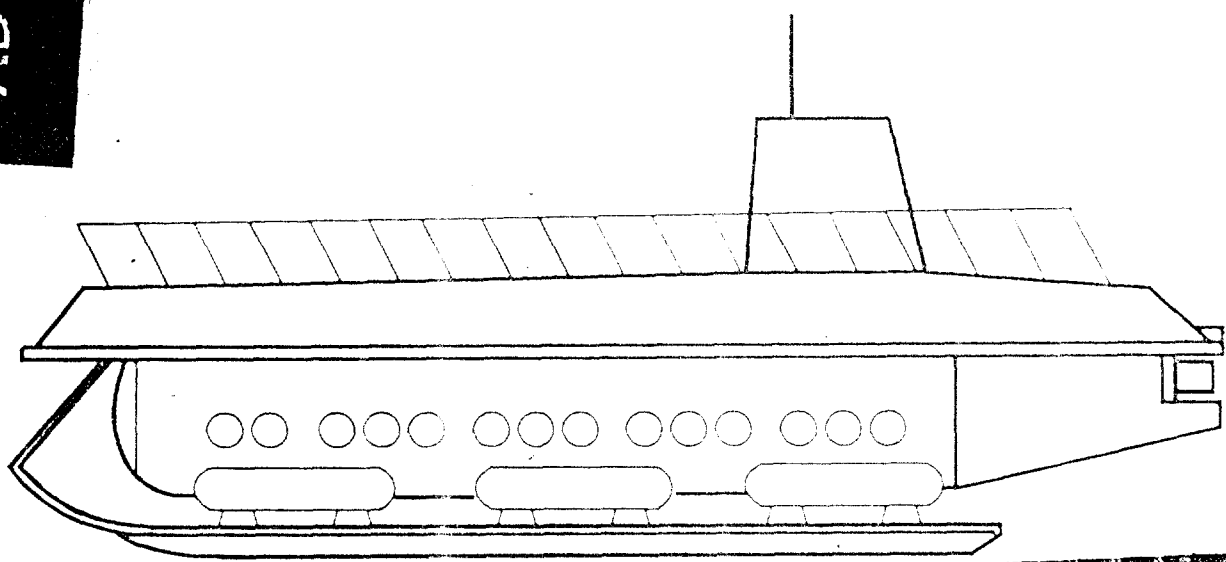
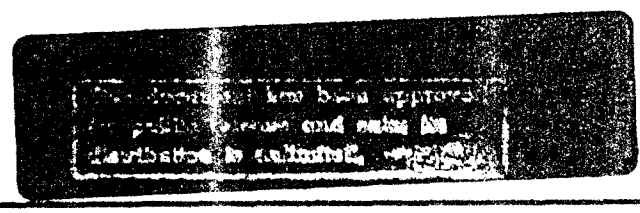
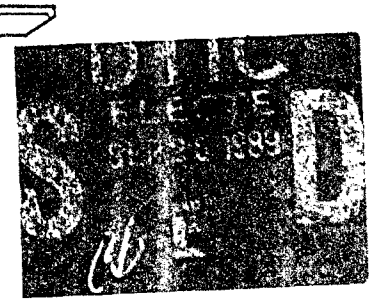
Final Report
August 1989







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16 Abstract

During the past few years, several private companies have been using passenger carrying submersibles to conduct underwater sightseeing tours for tourists. For submersible operations under U.S. jurisdiction, the Coast Guard is required by law to establish and enforce a certain minimum level of safety for vessels. The existing Coast Guard statutes and regulations were developed primarily for surface craft; many of the requirements cannot be applied to or are inappropriate for application to submersibles. Furthermore, for passenger carrying submersibles, the complexity and new concepts employed require that the Coast Guard develop methods to adequately evaluate their safety. This report presents the results of the system safety analysis conducted to identify and assess the hazards associated with the operation of passenger carrying submersibles. Included in this analysis is the definition of the submersible system in terms of the basic system elements: equipment and facilities, procedures, people, and the environment in which the submersible system operates. Hazard identification is accomplished through the creation of accident scenarios, the conduct of a Preliminary Hazard Analysis, and the development of Fault Trees. Finally, undesired events resulting from the hazards are assessed for event severity and the probability of event occurrence. General countermeasures to mitigate the undesired events are presented and the factors to be considered in the evaluation of the countermeasures are delineated.

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PREFACE

During the past few years, several private companies have been using passenger carrying submersibles to conduct underwater sightseeing tours for tourists. For submersible operations under U.S. jurisdiction, the Coast Guard is required by law to establish and enforce a certain minimum level of safety for vessels. The existing Coast Guard statutes and regulations were developed primarily for surface craft; thus, many of the requirements are not appropriate for application to submersibles. Furthermore, the complexity and new concepts employed for passenger carrying submersibles require that the Coast Guard develop methods to adequately evaluate their safety. This report presents the results of the system safety analysis conducted to identify and assess the hazards associated with the operation of passenger carrying submersibles.

This study was conducted under the direction of the Ship Design Branch, Safety and Oversight Section, Marine Technical and Hazardous Materials Division, Office of Marine Safety, Security and Environmental Protection, U.S. Coast Guard. The authors would like to express their deep appreciation to the Coast Guard staff for their support and guidance during the course of the analysis. The authors also wish to acknowledge the important contributions made by Albert E. Powell, Dana Stalcup and Deborah Lundberg of GP Taurio, Incorporated, for their support in this study and the preparation of the Preliminary Hazard Analysis, and John Witney of Sub-Aquatics, Inc., who provided assistance in understanding the operational concerns of the submersible operator. John Pritzlaff and R. Frank Busby made valuable contributions by providing the authors with an understanding of the how and why of submersible design and a review of the draft final report. In addition, Captain Rod Watterson of the U.S. Navy, Barrie Walden of Woods Hole Oceanographic Institute, and Brian Moriarty shared knowledge and experience which provided insight into potential hazards. Finally, the authors wish to express their appreciation to James H. Kelley for his assistance in editing this report.

METRIC / ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC

LENGTH (APPROXIMATE)

1 inch (in) = 2.5 centimeters (cm)
1 foot (ft) = 30 centimeters (cm)
1 yard (yd) = 0.9 meter (m)
1 mile (mi) = 1.6 kilometers (km)

AREA (APPROXIMATE)

1 square inch (sq in, in^2) = 6.5 square centimeters (cm^2)
1 square foot (sq ft, ft^2) = 0.09 square meter (m^2)
1 square yard (sq yd, yd^2) = 0.8 square meter (m^2)
1 square mile (sq mi, mi^2) = 2.6 square kilometers (km^2)
1 acre = 0.4 hectares (he) = 4,000 square meters (m^2)

MASS - WEIGHT (APPROXIMATE)

1 ounce (oz) = 28 grams (gr)
1 pound (lb) = .45 kilogram (kg)
1 short ton = 2,000 pounds (lb) = 0.9 tonne (t)

VOLUME (APPROXIMATE)

1 teaspoon (tsp) = 5 milliliters (ml)
1 tablespoon (tbsp) = 15 milliliters (ml)
1 fluid ounce (fl oz) = 30 milliliters (ml)
1 cup (c) = 0.24 liter (l)
1 pint (pt) = 0.47 liter (l)
1 quart (qt) = 0.96 liter (l)
1 gallon (gal) = 3.8 liters (l)
1 cubic foot (cu ft, ft^3) = 0.03 cubic meter (m^3)
1 cubic yard (cu yd, yd^3) = 0.76 cubic meter (m^3)

TEMPERATURE (EXACT)

$[(x - 32)(5/9)]\ °F = y\ °C$

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm) = 0.04 inch (in)
1 centimeter (cm) = 0.4 inch (in)
1 meter (m) = 3.3 feet (ft)
1 meter (m) = 1.1 yards (yd)
1 kilometer (km) = 0.6 mile (mi)

AREA (APPROXIMATE)

1 square centimeter (cm^2) = 0.16 square inch (sq in, in^2)
1 square meter (m^2) = 1.2 square yards (sq yd, yd^2)
1 square kilometer (km^2) = 0.4 square mile (sq mi, mi^2)
1 hectare (he) = 10,000 square meters (m^2) = 2.5 acres

MASS - WEIGHT (APPROXIMATE)

1 gram (gr) = 0.036 ounce (oz)
1 kilogram (kg) = 2.2 pounds (lb)
1 tonne (t) = 1,000 kilograms (kg) = 1.1 short tons

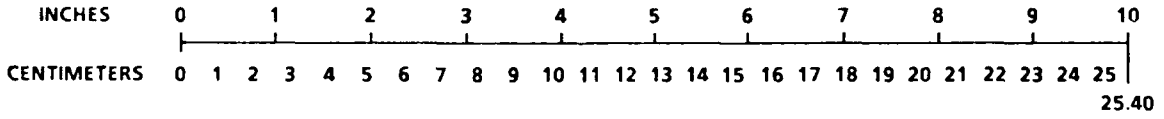
VOLUME (APPROXIMATE)

1 milliliter (ml) = 0.03 fluid ounce (fl oz)
1 liter (l) = 2.1 pints (pt)
1 liter (l) = 1.06 quarts (qt)
1 liter (l) = 0.26 gallon (gal)
1 cubic meter (m^3) = 36 cubic feet (cu ft, ft^3)
1 cubic meter (m^3) = 1.3 cubic yards (cu yd, yd^3)

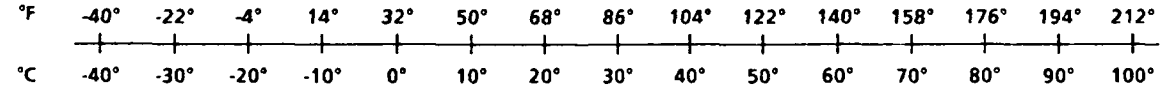
TEMPERATURE (EXACT)

$[(9/5)y + 32]\ °C = x\ °F$

QUICK INCH-CENTIMETER LENGTH CONVERSION



QUICK FAHRENHEIT-CELCIUS TEMPERATURE CONVERSION



For more exact and/or other conversion factors, see NBS Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50. SD Catalog No. C13 10 286.

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1. INTRODUCTION

During the past few years, several private companies have been using vessels known as submersibles to conduct underwater sightseeing tours. These tours provide passengers with the opportunity to travel beneath the ocean without knowing how to swim or wearing diving gear. The submersibles have viewports which provide passengers with panoramic views of the underwater environment, including coral reefs, tropical fish, shipwrecks, etc. Passenger submersible operations in the Caribbean Sea and the Pacific Ocean have carried many thousands of tourists during the last 5 years.

The U.S.Coast Guard is required by law to enforce a certain minimum level of safety for all U.S. flag vessels. The traditional approach has been to establish specific regulations based on historical experience and good engineering judgment. When designs are submitted which are beyond the scope of the regulations, the design is evaluated based on an equivalent safety level. For passenger carrying submersibles, the complexity and new concepts employed in these submersibles, requires that the Coast Guard develop methods to adequately evaluate their safety. Recognizing the need to identify and prevent the occurrence of submersible accidents, system safety analysis is a method which can be employed to assist the Coast Guard in evaluating these new concepts. This report presents the results of the system safety analysis of passenger carrying submersible operations conducted by the Transportation Systems Center.

1.1 BACKGROUND

For many years, non-military submersibles have been used to assist in industrial, experimental and research efforts; these submersibles have not been used in a service for which the existing inspection statutes and regulations would apply. For this new generation of submersible operations under U.S. jurisdiction, the statutes and regulations applicable to small passenger vessels are currently used by the Coast Guard to evaluate passenger submersibles. However, since these regulations were developed primarily for surface craft, many of the requirements cannot be applied to or are inappropriate for submersibles.

The regulations that are currently the basis for passenger submersible certification are found in 46 CFR Subchapter T-Small Passenger Vessels (less than 100 tons). The Coast Guard has also prepared guideline documents [1,2] which are intended to provide basic guidance and explain the current systems approach for submersible certification and stability.

The Coast Guard approach to the novel design and unique operational hazards of submersibles has been to require a level of safety that is equivalent to that required for a surface craft. This has been accomplished through a combination of design requirements, operational restrictions, and the requirement for redundant systems. This approach is intended to minimize any inherent hazards of underwater operation.

The Coast Guard has certified submersible operations in the U.S. Virgin Islands, Hawaii, and Guam by using a systems approach to evaluate the combined design, operations, dive site, and operator qualifications from the conceptual stage through the initial operation. After initial certification, the Coast Guard monitors the operations and periodically inspects the vessels used. Each operation has been evaluated individually because of the changing nature of the business and the lack of any specific regulations pertaining to submersibles.

1.2 PURPOSE AND SCOPE OF STUDY

The purpose of the system safety analysis presented in this document is to assist the Coast Guard in identifying potential safety issues associated with passenger carrying submersible operations. For the purpose of this study, a "submersible" is defined as any vessel carrying passengers and crew, which is capable of operating on the surface, submerging, operating submerged, surfacing and remaining afloat.

As stated previously, many of the requirements contained in the existing statutes and regulations cannot be applied to or are inappropriate for submersibles because these regulations were developed primarily for surface craft. The results of the analysis contained herein are intended to assist the Coast Guard in examining and modifying (as necessary) existing regulations to ensure that an equivalent level of safety is maintained in underwater operations.

In this study, the submersible system is defined as the facilities and equipment, the operating personnel and passengers, the procedures employed in operating the system, and the environment in which these elements operate. The tourist submersible is defined as less than 100 gross tons, expressly designed and built to carry more than 6 and up to 50 passengers (plus the crew) to depths of 150 to 250 feet.

The system safety concept and hazard resolution process have been utilized to perform the system safety analysis contained in this report. The overall approach used to perform the system safety analysis is contained in Figure 1-1.

Hazards identified and recommended corrective actions concern the equipment, environment, procedures, and people which comprise the total passenger submersible system. The hazards identified and resolved relate primarily to the operation of the submersible while it is submerged. In addition, a number of hazards pertaining to the interface between the submersible, the surface support and surface taxi vessels, and shore facilities have been considered.

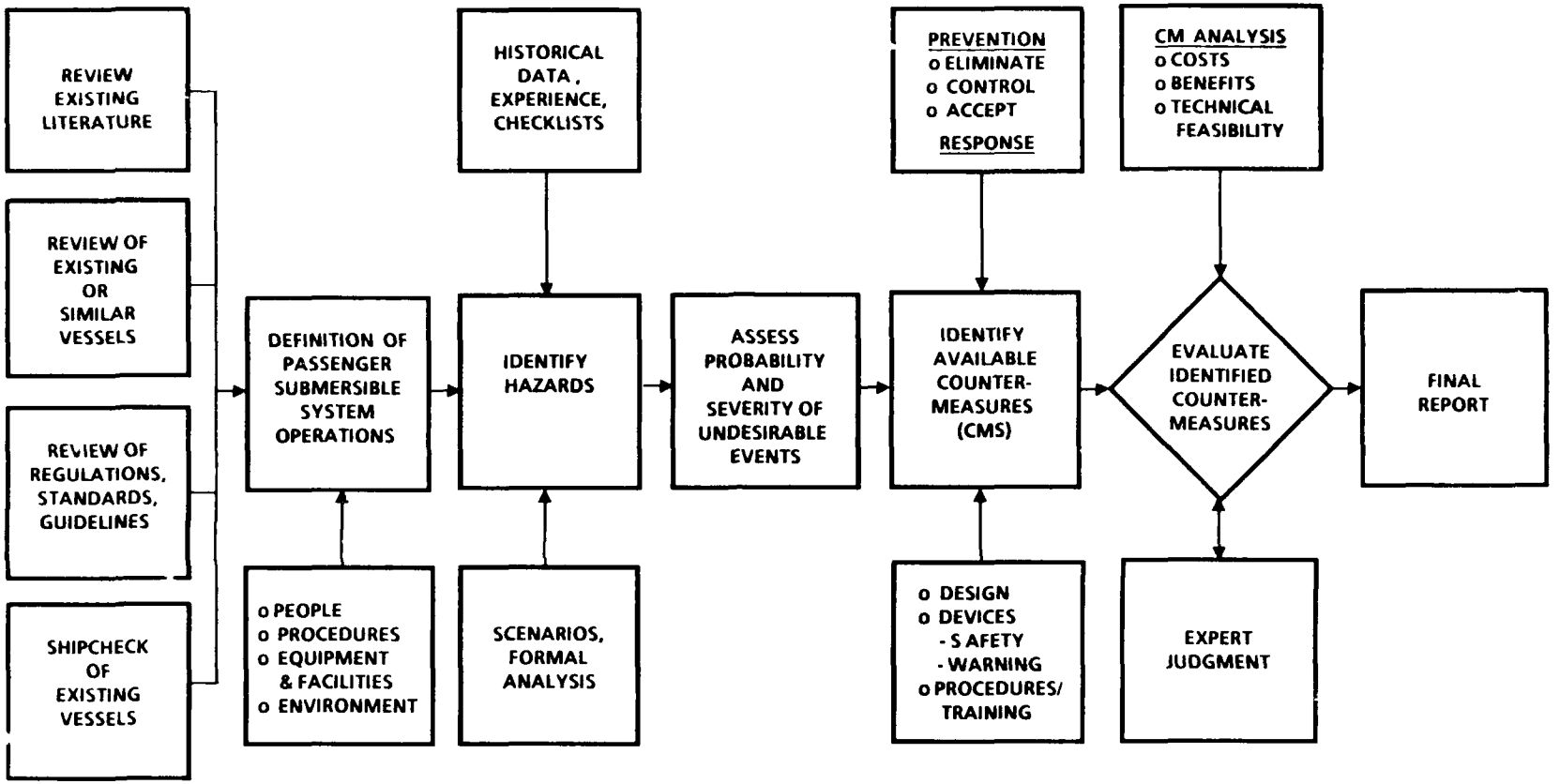


FIGURE 1-1. SYSTEM SAFETY ANALYSIS OF PASSENGER CARRYING SUBMERSIBLES

2. SYSTEM SAFETY APPROACH

2.1 SYSTEM SAFETY CONCEPT

System Safety is the application of special technical and managerial skills to the systematic, forward-looking identification and control of hazards throughout the life cycle of a project, program, or activity.[3] The concept calls for safety analyses and hazard control actions, beginning with the conceptual phase of a system and continuing through the design, production, testing, operation, maintenance, periodic inspection, and disposal phases. Applied to passenger carrying submersibles, this focus on the prevention of accidents by eliminating and/or controlling safety hazards in a systematic manner will serve to reduce the identified system hazards to the lowest practical level through the most effective use of resources. It should be noted that system safety analysis is not the same as failure analysis. This distinction is important because a hazard involves the risk of loss or harm while a failure does not always result in loss or harm. To be most effective, the System Safety approach employs a hazard resolution process from the Acquisition phase through the Operations phase of the particular system. The hazard resolution process depicted in Figure 2-1 presents the process which should be followed to ensure that passengers and crew are provided the highest degree of safety practical.

2.2 HAZARD RESOLUTION PROCESS

2.2.1 System Definition

The first step in the hazard resolution process is to define the physical and functional characteristics of the system to be analyzed. These characteristics are presented in terms of the major elements which make up the system: equipment, procedures, people, and environment. A knowledge and understanding of how the individual system elements interface with each other is essential to the hazard identification effort. Section 3 of this report describes the representative passenger carrying submersible system configuration.

2.2.2 Hazard Identification

The second step in the hazard resolution process involves the identification of hazards and the determination of their causes.

DEFINE THE SYSTEM

- DEFINE THE PHYSICAL AND FUNCTIONAL CHARACTERISTICS AND UNDERSTAND AND EVALUATE THE PEOPLE, PROCEDURES, FACILITIES AND EQUIPMENT, AND THE ENVIRONMENT

⇩

IDENTIFY HAZARDS

- IDENTIFY HAZARDS AND UNDESIRED EVENTS
- DETERMINE THE CAUSES OF HAZARDS

⇩

ASSESS HAZARDS

- DETERMINE SEVERITY
- DETERMINE PROBABILITY
- DECIDE TO ACCEPT RISK OR ELIMINATE / CONTROL

⇩

RESOLVE HAZARDS

- ASSUME RISK OR
- IMPLEMENT CORRECTIVE ACTION
  - ELIMINATE
  - CONTROL

⇩

FOLLOW-UP

- MONITOR FOR EFFECTIVENESS
- MONITOR FOR UNEXPECTED HAZARDS

⇩

FIGURE 2-1. HAZARD RESOLUTION PROCESS

When identifying the safety hazards present in a system, a major concern is that only a portion of the total number of system hazards has been identified. The type and quality of the hazard analysis will influence the total number of hazards identified. There are four basic methods of hazard identification that may be employed to identify hazards. These methods are:

- o Data from previous accidents (case studies) or operating experience,
- o Scenario development and judgment of knowledgeable individuals,
- o Generic hazard checklists, and
- o Formal hazard analysis techniques.

Section 4 describes the hazards identified for the representative passenger carrying submersible system using these methods.

2.2.3 Hazard Assessment

The third step in the hazard resolution process is to assess the identified hazards in terms of the severity or consequence of the hazard and the probability of occurrence. Figures 2-2 and 2-3 show the ranking criteria outlined in Military Standard: System Safety Program Requirements (Mil-Std. 882B)[4]. Figure 2-2 contains four severity categories and provides a general description of the characteristics which define the "worst case" event. Figure 2-3 lists the qualitative ranking of probability categories and describes the characteristics of each level.

The Hazard Risk Index (HRI), presented in Figure 2-4, is a value derived by considering both the severity and probability of a hazard. The HRI presents hazard analysis data in a format (i.e., 1 = Unacceptable) which assists the decision maker in determining whether hazards should be eliminated, controlled, or accepted. This provides a basis for logical management decision making, considering both the severity and probability of a hazard. It should be noted that the potential severity of a hazard cannot be reduced unless the hazard is completely eliminated through a major redesign. However, the probability and therefore the risk, can be greatly reduced by incorporation of safety devices, warning devices, procedures and training, or a combination involving two or all three.

Section 4 futher explains how the passenger carrying submersible system hazards were evaluated in terms of severity and probability.

CATEGORY	SEVERITY	CHARACTERISTICS
I	CATASTROPHIC	DEATH OR SYSTEM LOSS
II	CRITICAL	SEVERE INJURY, SEVERE OCCUPATIONAL ILLNESS OR MAJOR SYSTEM DAMAGE
III	MARGINAL	MINOR INJURY, MINOR OCCUPATIONAL ILLNESS OR MINOR SYSTEM DAMAGE
IV	NEGLIGIBLE	LESS THAN MINOR INJURY, OCCUPATIONAL ILLNESS OR SYSTEM DAMAGE

REFERENCE MIL STD 882B

FIGURE 2-2. HAZARD SEVERITY CATEGORIES

DESCRIPTION*	LEVEL	SPECIFIC INDIVIDUAL ITEM	FLEET OR INVENTORY**
FREQUENT	A	LIKELY TO OCCUR FREQUENTLY	CONTINUOUSLY EXPERIENCED
PROBABLE	B	WILL OCCUR SEVERAL TIMES IN LIFE OF AN ITEM	WILL OCCUR FREQUENTLY
OCCASIONAL	C	LIKELY TO OCCUR SOMETIME IN LIFE OF AN ITEM	WILL OCCUR SEVERAL TIMES
REMOTE	D	UNLIKELY BUT POSSIBLE TO OCCUR IN LIFE OF AN ITEM	UNLIKELY BUT CAN REASONABLY BE EXPECTED TO OCCUR
IMPROBABLE	E	SO UNLIKELY, IT CAN BE ASSUMED OCCURRENCE MAY NOT BE EXPERIENCED	UNLIKELY TO OCCUR, BUT POSSIBLE

* DEFINITIONS OF DESCRIPTIVE WORDS MAY HAVE TO BE MODIFIED BASED ON QUANTITY INVOLVED
** THE SIZE OF THE FLEET OR INVENTORY SHOULD BE DEFINED.

REFERENCE MIL STD 882B

FIGURE 2-3. HAZARD PROBABILITY CATEGORIES

FREQUENCY OF OCCURENCE	HAZARD CATEGORIES			
	I CATASTROPHIC	II CRITICAL	III MARGINAL	IV NEGLIGIBLE
(A) FREQUENT	IA	IIA	IIIA	IVA
(B) PROBABLE	IB	IIB	IIIB	IVB
(C) OCCASIONAL	IC	IIC	IIIC	IVC
(D) REMOTE	ID	IID	IIID	IVD
(E) IMPROBABLE	IE	IIE	IIIE	IVE

HAZARD RISK INDEX

IA, IB, IC, IIA, IIB, IIIA	1	UNACCEPTABLE
ID, IIC, IID, IIIB, IIIC	2	UNACCEPTABLE (MANAGEMENT DECISION REQUIRED)
IE, IIE, IIID, IIIE, IVA, IVB	3	ACCEPTABLE WITH REVIEW BY MANAGEMENT
IVC, IVD, IVE	4	ACCEPTABLE WITHOUT REVIEW

ADAPTED FROM MIL-STD 882B

FIGURE 2-4. HAZARD ASSESSMENT MATRIX

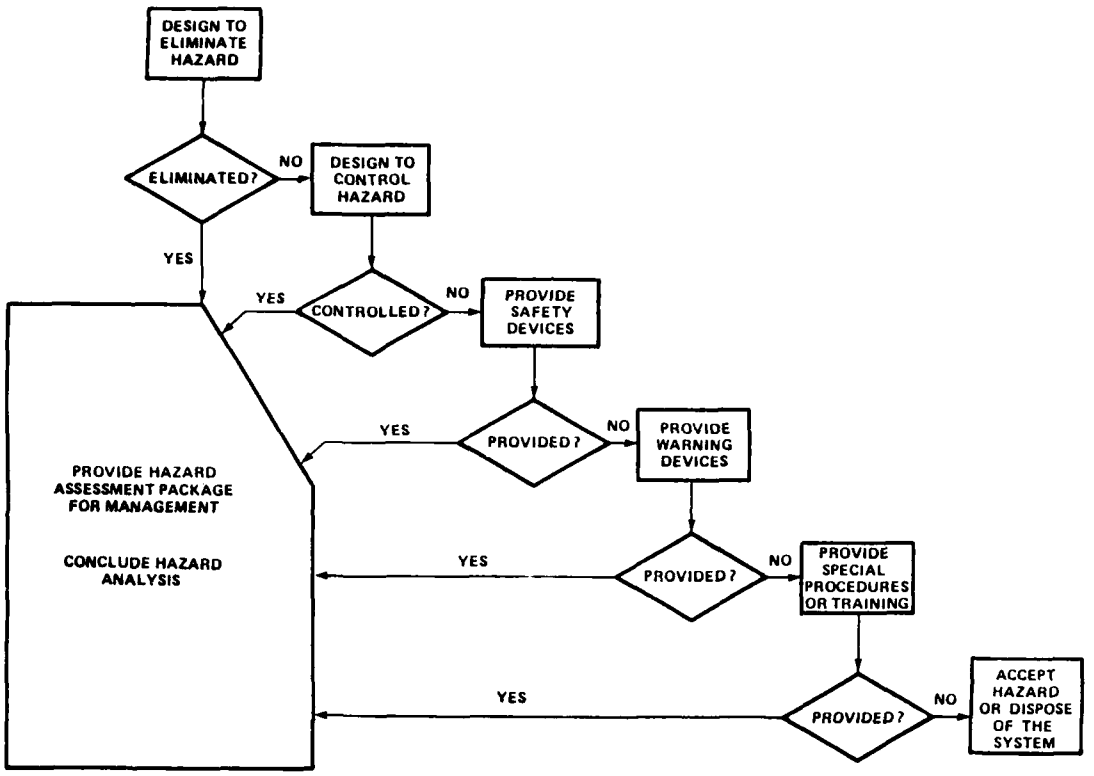
In addition, the hazard severity and probability ranking values and the risk assessment matrix were modified to assess the undesired events which could lead to a submersible passenger/crew casualty. Section 5 describes the assessment process used.

2.2.4 Hazard Resolution

After the hazard assessment is completed, hazards can be resolved by deciding to either assume the risk associated with the hazard or to eliminate or control the hazard. Various means can be employed in reducing the risk to a level acceptable to management. Figure 2-5 presents a hazard reduction precedence process that can be used to determine the extent and nature of preventive actions that can be taken to reduce the risk to an acceptable level. Resolution strategies or countermeasures in order of preference are:

Design to Eliminate Hazards

This strategy generally applies to acquisition of new equipment or expansion of existing systems; however, it can also be applied to any change in equipment or individual subsystems. However, in some cases hazards are inherent and cannot be eliminated completely through design.



Source: Roland & Moriarty, System Safety Engineering and Management. 1983.[3]

FIGURE 2-5. HAZARD REDUCTION PRECEDENCE

Design for Minimum Hazards

A major safety goal during the system design process is to include safety features that are fail-safe or have capabilities to handle contingencies through redundancies of critical elements. Complex features that could increase the likelihood of hazard occurrence should be avoided. Damage control, containment, and isolation of potential hazards, along with gradual system performance degradation, should be specified through system safety inputs. The safety inputs should be implemented in addition to other traditional design considerations.

Safety Devices

Known hazards which cannot be eliminated or minimized through design may be controlled through the use of appropriate safety devices. This could result in the hazards being reduced to an acceptable risk level. Safety devices may be a part of the system, subsystem, or equipment.

Warning Devices

Where it is not possible to preclude the existence or occurrence of an identified hazard, visual or audible warning devices may be employed for the timely detection of conditions that precede the actual occurrence of the hazard. Warning signals and their application should be designed to minimize the likelihood of false alarms that could lead to creation of secondary hazardous conditions.

Procedures and Training

Where it is not possible to eliminate or control a hazard using one of the aforementioned methods, safe procedures and/or emergency procedures should be developed and formally implemented. These procedures should be standardized and used in all test, operational, and maintenance activities. Personnel should receive training in order to carry out these procedures.

Hazard Acceptance/System Disposal

Where it is not possible to reduce a hazard by any means, a decision must be made to either accept the hazard or dispose of the system.

For this report, risk reduction countermeasures were developed to address passenger carrying submersible undesired events identified in the hazard scenarios, hazard checklists, and formal analyses. Section 6 contains a complete discussion of these countermeasures. Section 7 contains a review of an assessment of countermeasure effectiveness in terms of effectiveness, cost of implementation, and enforcement.

2.2.5 Follow-up

The last step in the hazard resolution process is follow-up. It is necessary to monitor the effectiveness of recommended countermeasures and ensure that new hazards are not introduced as a result. In addition, whenever changes are made to any of the system elements (equipment, procedures, people, and/or environment), a hazard analysis should be conducted to identify and resolve any new hazards.

3. SYSTEM DEFINITION

The first step in performing a hazard analysis is to define the system. The system definition contained in this section briefly describes the various physical and functional characteristics of a representative passenger carrying submersible system.

3.1 GENERAL

A "submersible" is herein defined as any vessel carrying passengers and crew, which is capable of operating on the surface, submerging, operating submerged, surfacing and remaining afloat. The submersible operates in conjunction with a surface support vessel. Existing passenger carrying submersible operations vary in size, design, construction, operating characteristics (propulsion, steering, etc.) and depth and location of the dive site.

The representative submersible described herein is expressly designed and built to carry more than 6 and up to 50 passengers (plus the crew) to depths of 150 to 250 feet. Currently, all dive sites are located in tropical waters.

For the purposes of this hazard analysis, the representative tourist submersible operation will utilize a submersible (less than 100 gross tons and carrying more than 6 passengers), surface support and passenger ferry vessels, and shore facilities (mooring and maintenance). Trained company personnel who operate the vessels and conduct the underwater tours are also included in the operation.

Major elements which make up the system are briefly reviewed in terms of equipment/ facilities, environment, procedures, and people.

3.2 EQUIPMENT/FACILITIES

The equipment and facilities element is comprised of the passenger submersible, surface vessels (support and passenger taxi), and shore facilities (for docking, maintenance and rescue recovery equipment /facilities).

3.2.1 Passenger Submersible

The passenger submersible provides an enclosed, controlled environment for tourists and crew to occupy while traveling to different depths and locations beneath the surface of the sea. The representative passenger submersible is subject to the

requirements of the Code of Federal Regulations (CFR) Title 46 Shipping, and Title 33 Ports and Waterways Safety, as contained in Table 3-1. Figure 3-1 indicates the typical location of several passenger submersible systems. The representative passenger submersible consists of the following systems and subsystems:

3.2.1.1 Hull

Pressure hull (main structure).

Exostructure (exterior attachments, i.e., fairing, ballast tanks, conning tower, deck railings and plates, skids, lifting hooks, etc.).

Penetrations (hatches, viewports, electrical, mechanical, etc., and other equipment).

Interior arrangement (separate space for pilot, passenger seating, equipment, and storage).

3.2.1.2 Ballast/Trim

Ballast Systems ("hard" - variable, "soft" - air, fixed/jettison weight, and syntactic buoyancy foam, and other insulation).

Trim (adjustment of the longitudinal inclination of the vessel by either the use of movable trim weight or the variable ballast system).

3.2.1.3 Piloting

Steering gear, rudder, thrusters, depth gauge, gyro, and compass.

Exterior running lights.

3.2.1.4 Instrumentation, Monitoring, Alarms

Gauges and/or indicators to monitor submersible depth, heading, attitude, condition of equipment, interior and exterior pressure, temperature, humidity, levels of oxygen and carbon dioxide, and water level within ballast tanks.

Visual or audible alarms to indicate unsafe conditions or equipment failures and detect water leaks or malfunctions.

3.2.1.5 Electrical

Power supply source (high and low capacity batteries).

Power distribution system.

Electrical cables, wiring, and relay panels.

Circuit breakers and power cut-outs to shut off power and isolate equipment as necessary.

TABLE 3-1. EXISTING CFR REGULATIONS APPLICABLE FOR SUBMERSIBLES (LESS THAN 100 TONS, CARRYING MORE THAN 6 PASSENGERS)*

46 CFR SHIPPING (As applicable)

Subchapter T - Small Passenger Vessels (Under 100 Gross Tons)

Part 175 General Provisions
Part 176 Inspection and Certification
Part 177 Construction and Arrangement
Part 180 Lifesaving Equipment
Part 181 Fire Protection Equipment
Part 182 Machinery Installation
Part 183 Electrical Installation
Part 184 Vessel Control and Misc. Systems and Equipment
Part 185 Operations

Subchapter B - Merchant Marine Officers and Seamen

Part 10 Licensing of Maritime Personnel
Part 12 Certification of Seamen
Part 15 Manning Requirements

Subchapter F - Marine Engineering

Part 50 General Provisions
Part 52 Power Boilers
Part 53 Heating Boilers
Part 54 Pressure Vessels (See also 49 CFR Transportation, Subchapter C - Hazardous Materials Regulations)
Part 55 Nuclear Power Plant Components
Part 56 Piping Systems and Appurtenances
Part 57 Welding and Brazing
Part 58 Main and Auxiliary Machinery and Related Systems
Part 59 Repairs to Boilers, Pressure Vessels and Appurtenances
Part 61 Periodic Tests and Inspections
Part 63 Control Systems for Automatic Auxiliary Heat Equipment
Part 64 Marine Portable Tanks

Subchapter J - Electrical Engineering

Part 110 General Provisions
Part 111 Electrical Systems-General Requirements
Part 112 Emergency Lighting and Power Systems
Part 113 Communications and Alarm Systems and Equipment

Subchapter N - Dangerous Cargoes

Part 147 Regulations Governing Use of Dangerous Articles as Ships Stores and Supplies On Board Vessels

*As of January 4, 1989

TABLE 3-1. EXISTING CFR REGULATIONS APPLICABLE FOR SUBMERSIBLES (LESS THAN 100 TONS, CARRYING MORE THAN 6 PASSENGERS) (Continued)

46 CFR SHIPPING (Continued)

Subchapter O - Certain Bulk Dangerous Cargoes

Part 150 Compatibility of Cargoes
Subpart 150.115 Definitions (Hazardous Materials)

Subchapter Q - Equipment, Construction, and Materials: Specifications and Approvals

Part 160 Lifesaving Equipment
Part 161 Electrical Equipment
Part 162 Engineering Equipment
Part 163 Construction
Part 164 Materials

Subchapter S - Subdivision and Stability

Part 170 Stability Requirements for all Inspected Vessels
Part 171 Special Rules Pertaining to Passenger Vessels
Part 172 Special Rules Pertaining to Bulk Cargoes
Part 173 Special Rules Pertaining to Vessel Use
Part 174 Special Rules Pertaining to Specific Vessel Types

Subchapter V - Marine Occupational Safety and Health Standards

Part 197 General Provisions
Subpart B Commercial Diving Operations

33 CFR NAVIGATION (As Applicable)

Subchapter O - Pollution

Part 155 Oil Pollution Prevention Regulations for Vessels
Part 159 Marine Sanitation

Subchapter P - Ports and Waterways Safety

Part 160 General
Part 161 Vessel Traffic Management (specifics for Puget Sound, etc.)
Part 162 Inland Waterways Navigation Requirements (specifics for rivers, etc.)
Part 164 Navigation Safety Regulations (for 1600 gross tons except St L. Seaway)
Part 165 Regulated Navigation and Limited Access Areas (by CG district)
Part 166 Shipping Safety Fairways (fairways and anchorages, Gulf of Mexico and Calif.)
Part 167 Offshore Traffic Separation Schemes (for U.S. ports)

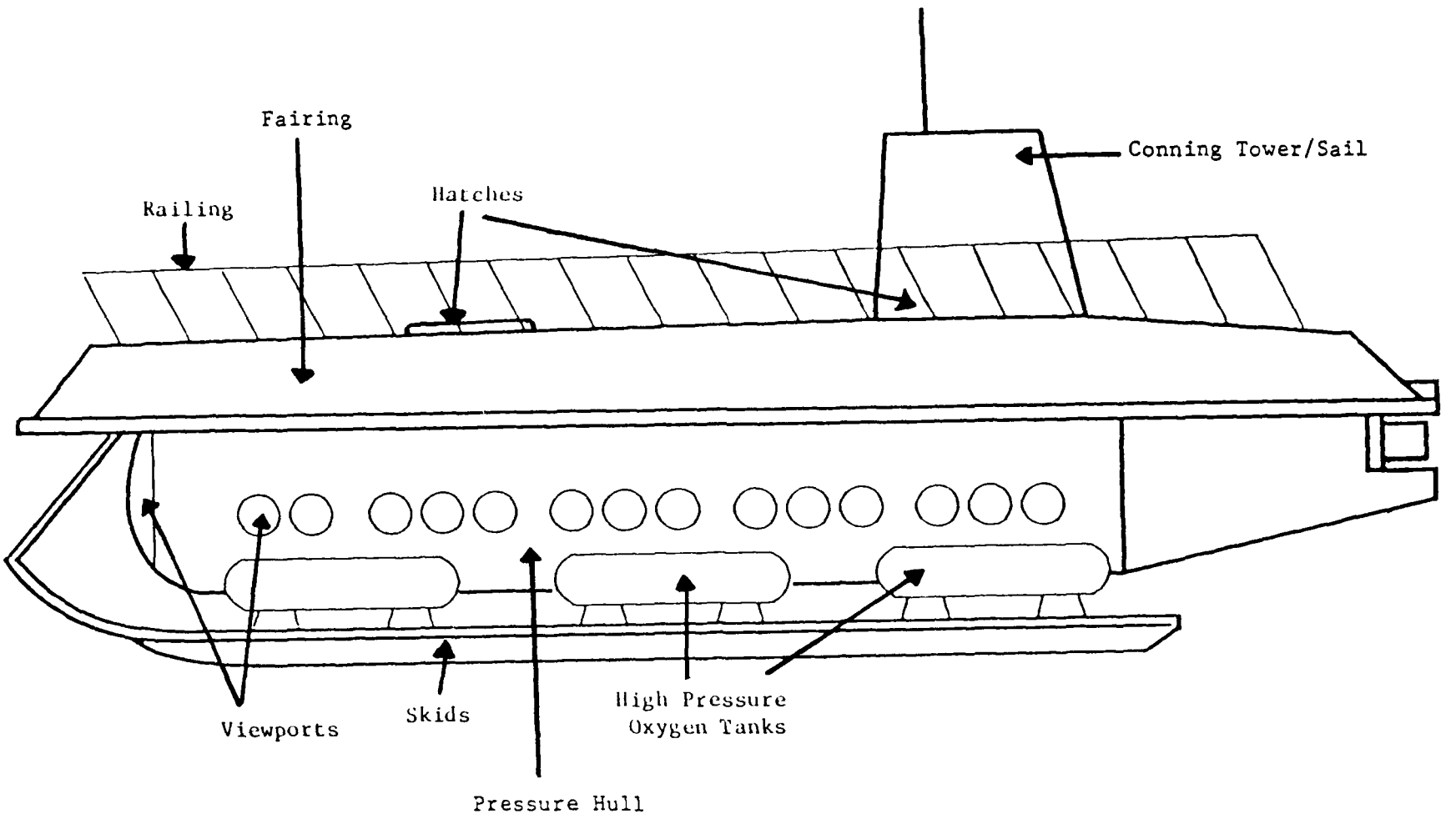


FIGURE 3-1. REPRESENTATIVE PASSENGER CARRYING SUBMERSIBLES

3.2.1.6 Lighting

Interior lighting

- Main passenger area, pilot console and hatchways
- Selected lighting fixtures connected to the emergency power supply

Exterior

- Running lights
- Flood lights for viewing

3.2.1.7 Propulsion

Main propulsion thrusters (propellers and motors or water jets).

Vertical thrusters to assist with the ballast system in ascending and descending.

Horizontal thrusters mounted longitudinally to move the vessel forward or astern, and assist the vessel in turning or moving sideways.

3.2.1.8 Hydraulics (if used)

Hydraulic fluid, pump(s), valve(s) and hoses to operate the steering controls, trim weight, and ballast systems.

3.2.1.9 Life Support

Oxygen supply system (high pressure storage tank (cylinders) necessary to maintain an oxygen level of approximately 21%.

Carbon dioxide (CO_2) removal (scrubber) system.

- Suction fan/motor to draw or blow air

- Cannisters containing a chemical powder which chemically absorbs the CO_2 to maintain a level at or below 0.5% by volume.

Atmospheric control system to remove contaminates, particulates, and odors; also controls humidity and temperature.

3.2.1.10 Communications

"Ship to ship" - Multichannel VHF marine band radio communications.

"Ship to sub" - Underwater telephone (UWT) which operates on dual frequencies and allows through-water acoustic communications with support vessels while the submersible is submerged.

Transducers for the UWT telephone mounted on the top as well as on the bottom of the submersible to permit communications when the submersible is submerged, on or near the surface

Intercom system (for internal communication between submersible crewmembers and from the crew to the passengers).

3.2.1.11 Lavatories (If provided)

Toilet and a sink.

No drinking water (exception: emergency supply).

3.2.1.12 Emergency Equipment

A Halon 1211 fire extinguisher for use when no passengers are on board and the hatch is open. A Halon 1301 fire extinguisher for use when passengers are present and the hatch is closed.

First aid kit.

Halon 1301 fire extinguishing system (with a concentration of no greater than 5% by volume).

Inflatable life jackets for each passenger and crewmember.

Food and water supplies for each passenger and crew in sufficient quantities to sustain life for 72 hours.

Reserve 72-hour supply of oxygen and 72-hour supply of CO_2 absorbent chemical for the CO_2 scrubber system.

Individual breathing units (to filter out smoke from a fire) for each passenger and crew with the exception of the pilot. The pilot is provided with a separate air system and breathing mask.

A separate reserve emergency power supply source for backup power emergency lights, operation of the reserve oxygen and CO_2 scrubber systems, communications, etc., capable of functioning for 72 hours.

Bilge pump to pump out accumulated water (condensation, leaks etc.) when submersible is on the surface.

Emergency manual controls, including switches and overrides to isolate or transfer power, etc.

Exterior manual controls for hatch operation, blowing of the air ballast tanks, and the release of jettison drop weights from the outside of the submersible.

Locating devices

- Emergency buoy or a dye marker (manual release)
- Acoustic beacon (pinger mode of UWT) connected to the emergency power supply to provide submersible location at depths of more than 200 feet.

3.2.2 Surface Support Vessel

The surface support vessel remains at the dive site at all times while the submersible is in the area. The support vessel maintains constant communication with the submersible and carries special equipment to be used during emergencies or for rescue or recovery. The support vessel is not required to be inspected or certified. However, it is subject to regulations contained in 46 CFR, Subchapter C Uninspected Vessels.

3.2.2.1 Communications

In addition to the capability of communicating with the passenger taxi vessel, other surface vessels, and the shore, the surface support vessel has the capability of directly communicating with the submersible in three ways:

VHF radio while the submersible is on the surface,

Underwater telephone when the submersible is underwater, and

Special marker boards and markers which can used by divers to write messages to the submersible crew.

3.2.2.2 Special Equipment

Spotlights which can be directed at a particular location, a marking buoy to indicate the location of the submersible if necessary, rope, cables, and other tools.

Self-contained underwater breathing equipment with air storage cylinders which can be used by scuba divers. These divers (depending on operating depth) can assist the submersible in surfacing (by using exterior air ballast controls, or releasing jettison weight), attaching markers or lift lines/cables, and flotation devices.

3.2.3 Passenger Taxi (Ferry) Vessel

The taxi vessel transports passengers from the shore facility to the dive site. The current Coast Guard requirement for the capacity of this vessel is twice the maximum number of passengers and crew which could be carried aboard the submersible.

3.2.3.1 General

If the vessel is more than 100 gross tons, construction and arrangement should be according to 46 CFR Subchapter H, Part 72; Lifesaving equipment should be according to Part 75; Fire protection equipment to Part 76; Vessel control and miscellaneous systems and equipment to Part 77; and Operations to Part 78. Also applicable are parts of 46 CFR Subchapter F, Marine Engineering; Subchapter J, Electrical Engineering; Subchapter Q, Equipment, Construction and Materials: Specifications and Approvals; Subchapter S, Subdivision and Stability; and finally, 33 CFR Subchapter O, Part 155 Oil Pollution Prevention, and Part 159 Sanitation.

If the vessel is less than 100 gross tons, the vessel is subject to all CFR regulations cited above with the substitution of 46 CFR Subchapter T (for 46 CFR Subchapter H), including Part 176, Inspection and Certification; Part 177, Construction and Arrangement; Part 180, Lifesaving equipment; Part 181, Fire Protection Equipment; Part 182, Machinery Installation; Part 183, Electrical Installation; Part 184, Vessel Control and Miscellaneous Systems and Equipment, Part 185 Operations; and Part 186 Manning.

3.2.3.2 Communications

In addition to the capability of communicating with the surface support vessel, other surface vessels, and the shore, the passenger taxi vessel is able to communicate with the submersible through VHF radio while the submersible is on the surface and underwater telephone while the submersible is underwater.

3.2.4 Shore Facilities

Shore facilities consist of a dock which allows an orderly loading and unloading of passengers from the passenger taxi vessel, space for docking of all vessels, storage, and maintenance.

Shore facilities also maintain rescue capabilities, either company owned or available upon notification (short notice) from other sources. Communications equipment capable of contacting organizations with rescue capabilities is maintained. Emergency equipment may include cranes, a remotely operated vehicle (ROV), or attachable buoyancy/flotation devices capable of lifting the submersible from the sea bed (depending on the depth of operations).

3.3 ENVIRONMENT

This element of the submersible operation system consists of the environment in which the submersible operates and the environment provided to passengers. The environment has been categorized as follows: operating, physical, and passenger.

3.3.1 Operating Environment

The number of trips (dives) by the submersible, distance to the dive site, duration of dive, and night-time operation, are all determined by company policy. Factors which influence these operations include equipment capability and capacity, number of crew and experience, weather conditions, and Coast Guard or local authority requirements.

3.3.2 Physical Environment

The location and route which the submersible follows in conducting the underwater tour is selected to offer passengers the maximum visual experience. Visibility, weather, and sea state are also considered because of the transfer of passengers to and from the submersible while located away from docking facilities.

Tours follow consistent paths over the known sea bed bottom. The dive site can be located at a distance of 1 to 3 miles from shore. Passenger submersible operations are presently conducted in tropical waters.

The normal operating depth while underwater varies between 40 and 250 feet. Maximum diving depth ranges between 150 and 250 feet. Water depth should not exceed the rated operating depth of the submersible.

The maximum forward speed of the submersible while submerged is 2 knots. While the tour is underway, the normal cruising speed is 0.5 to 1.0 knots.

3.3.3 Passenger Environment

3.3.3.1 Submersible

The passenger compartment of the submersible provides an environment in which passengers can travel underwater protected from direct contact with marine life or hazards and without the need for special individual breathing equipment. An interior atmospheric pressure is maintained equal to the surface (1 atmosphere). Temperature and humidity are maintained at a comfortable level; the oxygen level is maintained at approximately 21%.

The length of time that the passengers actually spend underwater during each dive ranges from 45 minutes to one hour. Large viewports which allow passengers a panoramic view outside are located along both sides of the submersible. The interior height of the passenger cabin varies with location in the submersible while the interior length varies according to passenger capacity. Submersible capacity varies between 6 and 50 passengers (not including the crew).

Separate supplies of emergency provisions (food, water, oxygen, CO_2 absorbent) sufficient to maintain life for 72 hours are carried onboard the submersible.

3.3.3.2 Passenger Taxi Vessel

The taxi vessel transports passengers from the shore facilities to the dive site. The passenger capacity of the taxi vessel is twice the capacity of the submersible. The length of time to reach the dive site by the taxi vessel from shore can range from 10 to 40 minutes. Passengers may transfer to the submersible by means of ramps/gangways equipped with railings or may simply transfer by stepping directly from the taxi vessel to the submersible.

3.4 PROCEDURES

This element of the system consists of the procedures associated with the operation of the submersible. The procedures are used by the submersible crew, surface vessel (support and taxi) crews and shore staff. Categories of procedures include normal operating procedures (for day and night dives), documentation procedures, communication procedures, maintenance procedures, training procedures, and emergency procedures.

3.4.1 Normal Operations

3.4.1.1 Standard Operating Procedures

Standard operating procedures (SOPs) apply to the entire sequence of events and procedures which occur before, during, and after submersible dives during day or night operations. Operations at night are assumed to parallel the SOPs used during day operations with the addition of procedures for the checking and use of lighting (dock, exterior lights of surface vessels and submersible). The SOPs comprise the following sequence of phases.

Phase 1 - includes assignment of crew duties and completion of procedures to check the proper operation of all vessels and equipment before the vessels leave the shore for any particular day. In addition, the weather, sea state, and other conditions are reviewed and the dive site verified (if there are alternate approved locations).

Phase 2 - concerns submersible travel to the dive site.

Phase 3 - covers passenger travel to the dive site and transfer to the submersible. On shore, the taxi vessel is loaded with passengers and transports them to the dive site. Positioning of the taxi vessel alongside the submersible and casting on of lines is completed after arrival at the dive site. Hatches are then opened, previous passengers (if any) are off-loaded, and a new load of passengers boarded.

Phase 4 - involves the actual preparation for the scheduled dive. Procedures include closing of the hatches, casting off of lines and performing a pre-dive check by the submersible crew prior to descent. In addition, the location and operation of emergency equipment (i.e., oxygen masks and life preservers) is explained to the passengers.

Phase 5 - consists of the submersible crew carrying out the procedures necessary to descend. After the submersible reaches the desired depth, ballast is then adjusted so that a slight positive buoyancy is maintained throughout the dive.

Phase 6 - After descent to the operating depth is completed, the submersible pilot maneuvers along the selected route for the underwater tour. The surface support vessel keeps the area directly above the submersible clear of any other surface

vessels and maintains communications. The surface taxi vessel returns to the dock, off-loads passengers, boards new passengers, and returns to the dive site.

Phase 7 - Upon the completion of the dive, the submersible pilot notifies the surface support vessel of intention to end the dive and then carries out ascent procedures. Upon reaching the surface, the procedures for loading and unloading passengers are repeated with the addition of a post-dive check by the submersible crew prior to the boarding of new passengers. Procedures described in phases 3 through 7 are repeated for each subsequent dive.

Phase 8 - This phase occurs at the end of the day. The submersible is towed to the dock or maintenance facility. The other vessels also return and final internal and external checks are made of the submersible by the vessel crew. Checks are also made of the surface vessel equipment. A post-dive brief is completed by all operating personnel, problems are identified, logs and other records are completed, and necessary maintenance is assigned and performed.

3.4.1.3 Documentation Procedures

As applicable, checklists of operational tests, system status, communication, and maintenance logs, and other records are completed and signed by appropriate submersible, support vessel, and maintenance personnel after each dive and on a daily basis.

3.4.1.4 Communication Procedures

The submersible vessel initiates or returns communications with the surface support vessel at 10 to 15 minute time intervals, and requests clearance to surface at the end of the dive (or for emergency ascent).

For each dive, the surface support vessel verifies the operation of the underwater telephone, provides the submersible with clearance to open and close hatches, clearance to open or close air ballast vents, and clearance and heading for the submersible to dive or surface. The surface support vessel initiates or returns communications with the submersible vessel every 10 to 15 minutes. If the submersible does not receive any contact from the surface support vessel for more than 20 minutes, the pilot tries once more to reestablish contact. If that fails, the submersible pilot aborts the dive and returns to the surface.

The surface taxi vessel maintains contact with the surface support vessel at all times while at the dock and en route to the dive site. The taxi vessel also informs the support vessel of the passenger count and estimated time of arrival for each trip to the dive site. After boarding of passengers is completed, the taxi vessel radios its heading prior to proceeding back to the dock.

3.4.2 Maintenance Procedures

Scheduled and specific procedures are followed for repairs, modifications, replacement of equipment, removal, and any other routine maintenance for the submersible or surface vessels.

3.4.3 Emergency Procedures

Various types of emergency situations could occur, involving the submersible itself, or one or both of the surface support vessels. Submersible emergency situations could involve:

- Collision (underwater or surface),
- Entanglement,
- Fire,
- Flooding,
- Loss of power,
- Passenger illness,
- Loss of air in ballast/trim system,
- Stranded on bottom,
- Emergency or uncontrolled ascent,
- Oxygen leak/CO_2 removal system failure, and
- Loss of communication.

For specific submersible emergency situations, predetermined procedures for emergency communications, abort of dive, and use of emergency equipment are followed by the crew as appropriate on each vessel, to safeguard the safety of submersible vessel passengers and crew, and to ensure their rescue/evacuation from the vessel and safe return to shore. Although the submersible pilot normally requests clearance from the surface support vessel to ascend, the pilot may abort the dive and surface during emergency conditions.

The surface vessels may develop an emergency situation (i.e., crew illness, fire, collision, change of sea state and other weather conditions). Crews of each vessel again follow predetermined emergency procedures applicable to each situation.

3.5 PEOPLE

The final element of the passenger submersible system consists of people, including company personnel and passengers.

3.5.1 Company Personnel

3.5.1.1 Duties

Company personnel have different duties and authority depending on their assigned responsibilities. The General Manager is the person in charge of all aspects of the local operation, including sales, advertising, financial, etc. The Operations Manager is responsible for the day-to-day operation of the submersible and surface vessel operations. Other staff sell tickets and assist passengers in boarding the passenger taxi ship, and perform necessary maintenance and repair.

Company personnel directly involved with operations are the submersible crew, the crew for the surface taxi ship vessel which transports passengers to the dive site, and the crew for the surface support vessel which provides dive site support (i.e., assist in loading passengers on and off the submersible, maintain communications, track the submersible , protect the dive site area, etc.)

Submersible Personnel

The minimum submersible personnel consists of a pilot and copilot. The pilot operates the vessel while it is submerged. The copilot assists the pilot in the operation of the vessel, provides explanations of underwater attractions to passengers, and provides other assistance as necessary. The copilot is capable of taking over submersible operations.

Surface Vessel Personnel

The surface (support and taxi) vessels each have a captain and a deckhand. The surface vessels are operated under the direction of a captain with the assistance

of deckhands. The captain of the surface support vessel is designated as having overall control of all company vessels at the dive site.

Rescue/Recovery Personnel

Qualified divers or other personnel, knowledgeable in the operation of emergency equipment, should be either available on the surface vessels or at shore facilities.

3.5.1.2 Qualifications and Experience

The pilot and copilot of the submersible have completed the company training program. The pilot has obtained submersible operating experience while serving as a copilot. The submersible crew is familiar with the area of the operating site. Support personnel also have completed the company training program.

Submersible personnel are certified by the Coast Guard. In addition, applicable Coast Guard regulations regarding licensing, training, and manning requirements for the surface vessels are followed.

3.5.1.3 Training

Initial classroom and practical training in the proper operation of the submersible and other vessel operations is provided to appropriate personnel. Refresher training is provided on an annual basis to all personnel. Separate training in how to respond to emergency situations, including emergency procedures and operation of emergency equipment is provided as part of the initial and refresher training.

3.5.2 Passengers

Passengers who travel on the submersible are persons who probably have never been on a submarine before. They do not necessarily know how to swim. Passenger age can vary and some passengers may have disabilities such as hearing loss, heart disease, shortness of breath, etc. The number of passengers varies (see Environment).

4. HAZARD IDENTIFICATION

Having defined the system, the next step in the hazard resolution process is the identification of potential hazards. When identifying the safety hazards present in a system, a major concern is what portion of the total number of system hazards has been identified. The quality or type of hazard analysis will greatly influence the total number of hazards identified.

4.1 HAZARD IDENTIFICATION APPROACH

There are four basic methods of hazard identification that may be employed to identify hazards. These methods are:

- o Data from previous accidents (case studies) or operating experience,
- o Judgment of knowledgeable individuals and scenario development,
- o Generic hazard checklists, and
- o Formal hazard analysis techniques.

4.1.1 Data from Previous Accidents

Examination of previous accident experience can provide an insight into what has happened in the past. Passenger carrying submersibles (for the tourist trade) have been operating in the Caribbean and the Pacific Ocean for the last 5 years. This operating experience (exposure) of passenger carrying submersibles has not resulted in the occurrence of any deaths or serious injuries. Therefore, information from other data sources for other types of submersible usage and military submarines was reviewed to gain an insight into the kinds of potential emergency situations which could occur.

Insight into emergency situations involving industrial/research submersibles is provided in references 5 and 6. Although much of the military experience has been classified, reference 7 provides an excellent insight into peacetime submarine accidents. In the case of commercial research and industrial submersibles, there have been very few accidents. The low accident experience is due in large part to the good operating practices of the submersible industry. Moreover, the limited data available is insufficient to provide a thorough understanding of the variety of

potential hazards that may occur in submersible operations. In addition, identification of hazards solely through review of previous accident data or experience is not a satisfactory approach because identified hazards will be limited only to previous accidents while new and future hazards will not be identified.

4.1.2 Expert Opinion and Hazard Scenarios

Judgment by knowledgeable individuals was used to provide a starting point for the identification of the types of emergency situations or "undesirable events," which can occur. To assist in understanding the mechanism by which accidents occur, hazard scenarios have been developed. These scenarios briefly outline potential situations and equipment malfunctions which could impact on the safety of the submersible and the persons onboard. Scenarios include selected undesirable events (i.e., air contamination, fire, inability to surface, etc.) and a summary of possible causes and results. The scenarios are intended to represent potential real-world events and, as such, have been derived primarily from the experiences of research/industrial submersibles and military submarines.

The seven scenarios developed which represent typical submersible emergency situations are categorized as follows:

- Flooding,
- Inability to ascend or descend,
- Fire,
- Collision,
- Vessel isolation,
- Air contamination, and
- Passenger injury/illness.

A complete description of the scenarios is contained in Appendix A. Each of these types of emergency situations may be the result of a number of hazards and causal effects that involve a variety of events or conditions. Although a number of potential hazards and causal effects were identified, this initial effort identified only a limited portion of the hazards that may exist. The scenarios were also of limited assistance in identifying the potential for future accidents.

4.1.3 Generic Checklists

Generic checklists may also be used to identify potential hazards. With this approach, the depth of detail and applicability of the hazard checklists has an impact on the quality and quantity of hazards identified. Appendix B contains a generic checklist which groups hazards within the categories of basic design deficiencies, malfunctions, maintenance, environmental, and human factors.

4.1.4 Formal Analysis

A number of formal analysis methods are available for use in identifying hazards. The following sections present the two formal analysis methods which were employed to identify hazards associated with passenger carrying submersibles.

4.2 PRELIMINARY HAZARD ANALYSIS

Preliminary Hazard Analysis (PHA) is a basic hazard analysis technique used to identify hazards. The PHA is an inductive analysis technique which uses the bottom up approach (what happens if this hazard exists) to determine what the effect of a system event or system malfunction will be. The PHA format provided an organized, systematic framework to follow in presenting potential hazards, causes, recommendations, and hazard control references. A key point concerning this analysis, as used for this report, is that it provides a checklist and opportunity to consider a large number of potential hazards; some of which, however improbable, could occur. This is important because historical data and experience do not necessarily reflect all potential safety hazards and their effects.

4.2.1 PHA Development

The PHA is based on the passenger carrying submersible system contained in the system definition presented in Section 3 of this report. The PHA has been developed using the organizational approach shown on Figure 4-1. The three main elements of the submersible system are: Submersible, Surface/Shore, and General. Figure 4-1 also contains an organizational chart which presents the functional areas analyzed for each of the main elements. These functional areas are:

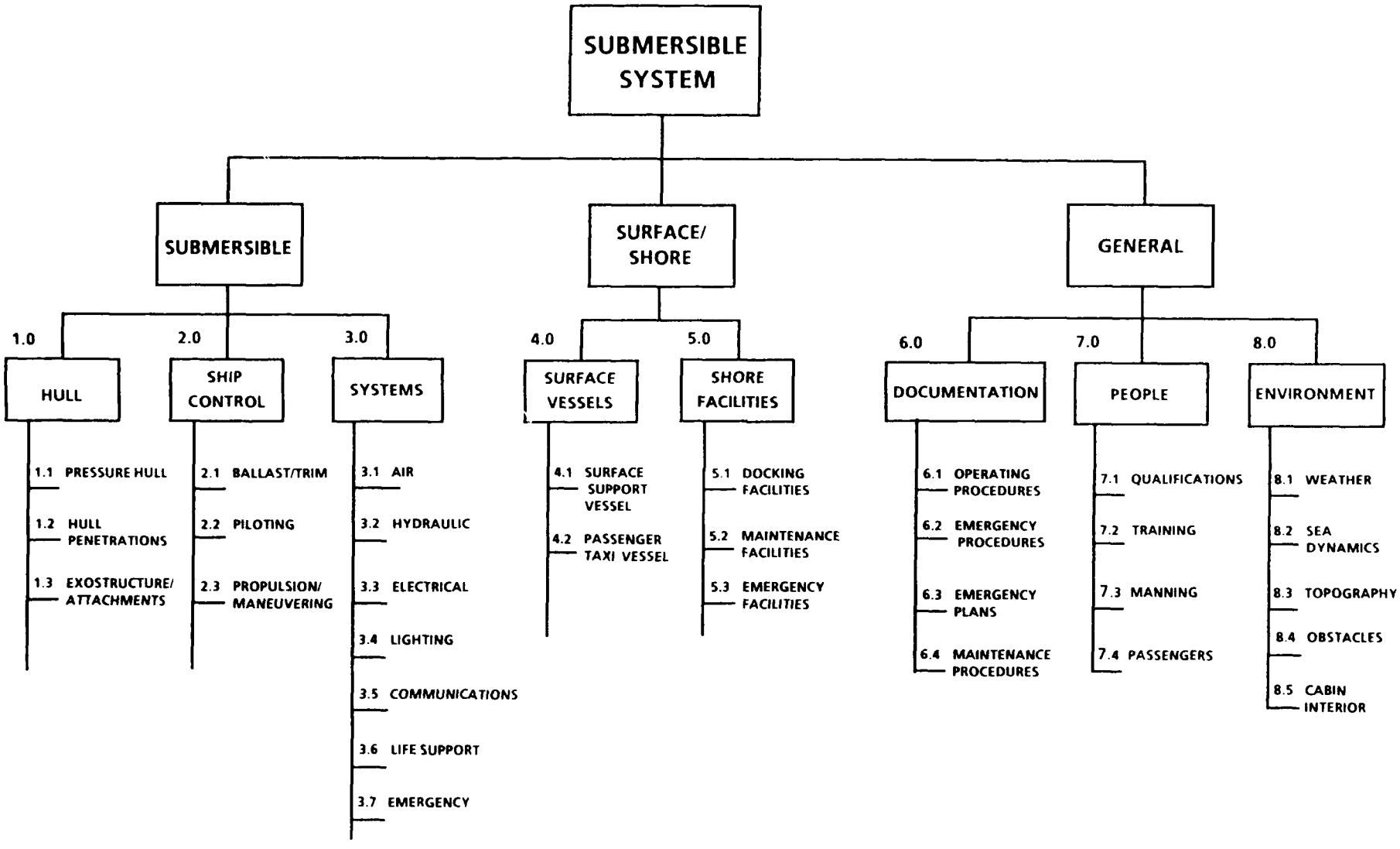


FIGURE 4-1. PHA ORGANIZATION

- o Hull,
- o Ship control,
- o Systems,
- o Surface vessels,
- o Shore facilities,
- o Documentation,
- o People, and
- o Environment.

Potential hazards and causes were identified for each of the systems and subsystems within the functional areas. Hazards were identified utilizing a review of the available literature, hazard scenarios described in Appendix A, and the generic checklist contained in Appendix B; and discussions with persons knowledgeable about submersible equipment and operations.

PHA worksheets were prepared which list the following:

- o Hazard description,
- o Potential causes,
- o Potential effects,
- o Risk Assessment Category,
- o Hazard Risk Index,
- o Recommended action for corrective actions,
- o Effect of recommendation,
- o Hazard control references (where available), and
- o Notes.

Figure 4-2 is an example of a PHA worksheet and is explained in the following text. The control number for each line item is contained in the first column. This number identifies the line item and is derived from the combination of numbers assigned to each of the systems, subsystems, and hazard descriptions. Where there is more than one causal factor for a specific hazard description, each of the causal factors is assigned a letter. For the example illustrated, the control number 1.1.01A results from the combination of the following: 1 for the Hull system, .1 for the Pressure Hull subsystem, and .01 for the hazard description, Implosion/Collapse. The A indicates that the first cause (of five in this case) of the hazard is Improper Design. The second

ELEMENT: SUBMERSIBLE
SYSTEM: HULL
SUBSYSTEM: PRESSURE HULL

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
1.1.01A	IMPLOSION OR FAILURE OF PRESSURE HULL	IMPROPER DESIGN OF PRESSURE HULL	FLOODING	ID	1	FOLLOW CFR, MTS, ASME, ABS AND NAVY FOR DESIGN OF PRESSURE HULL. USCG PLAN REVIEW.	IE	3	46 CFR 54, 197.328. MTS II, SECTION B.2.0 & B.4.0. ASME PVHO-1A, SECTION 1.3. ABS, SECTION 9. NAVMAT P-9290, APPENDIX B. USCG, MAY 87, P. 3.	
1.1.01B	IMPLOSION OR FAILURE OF PRESSURE HULL	IMPROPER MATERIAL SELECTION FOR PRESSURE HULL	FLOODING	IC	1	FOLLOW CFR, ASME, ABS, AND NAVY FOR PRESSURE BOUNDARY MATERIAL SPECIFICATIONS AND TESTING.	IE	3	46 CFR 176.05, 176.10, 177.10-1. ASME PVHO-1A, SECTION 1.2. ABS, SECTION 3. NAVMAT P-9290, APPENDIX A.	
1.1.01C	IMPLOSION OR FAILURE OF PRESSURE HULL	IMPROPER FABRICATION OF PRESSURE HULL	FLOODING	IC	1	FOLLOW CFR, ASME, ABS, AND NAVY FOR FABRICATION. INSPECTION DURING MANUFACTURING.	IE	3	46 CFR 177.10-1. ASME PVHO-1A, SECTION 1.3. ABS, SECTION 4. NAVMAT P-9290, CHAPTER 4 & SECTION B.3. INSPECTION: 46 CFR 176.05, 176.10, ABS, SECTION C.17.	

FIGURE 4-2. PHA WORKSHEET EXAMPLE

column of the PHA worksheet contains a brief description of each hazard while the potential causes are noted in the third column. The fourth column describes the potential effect of the specific hazard, in this case, Flooding. The fifth column contains the Risk Assessment Category (RAC) and the Hazard Risk Index (HRI) value assigned to each hazard. (Refer to Figure 2-4) The RAC represents the hazard risk in terms of both the severity and probability (e.g., ID indicates the hazard is "Catastrophic" and "Remote"). The RACs are grouped into four numerical HRI categories. The HRI value (e.g., 1 = Unacceptable) is used to actually determine what management action is necessary. The RAC and HRI are a subjective judgment open to other opinion since adequate data is unavailable to actually determine the probability. The recommendations presented in column six of the PHA worksheets describe methods which may be employed to either eliminate the cause or minimize the effect of each hazard. One or more recommendations are listed for each of the hazard causes identified. Many recommendations are based on existing rules, regulations, and guidelines. The effect of the recommendation in terms of changing the RAC and HRI is presented in column seven. (Note: This second RAC and HRI reflect a reduction in probability, but not severity.). The eighth column lists the applicable sections of regulations, rules, and guidelines which were used as reference sources for the recommendations. In cases where no reference was located, the term TBD (To be Determined) was used. The ninth column, "Notes," was used to indicate whether hazards were considered time dependent.

Hazard control references included applicable sections of the Code of Federal Regulations, Parts 46 and 33, ABS Rules for Building and Classing Underwater Systems and Vehicles, ASME/ANSI Safety Standard for Pressure Vessels for Human Occupancy, publications of the Marine Technology Society, U.S. Navy Systems Certification Procedures and Criteria Manual for Deep Submergence Systems, and U. S. Coast Guard passenger carrying submersible guidelines. A complete listing of the reference sources is contained in Appendix C. The ninth column, " Notes," was used to indicate whether hazards were considered time dependent.

4.2.2 PHA Findings

The PHA effort has focused primarily on the identification of hazards which could result in the following undesired events:

- Flooding,
- Fire/Explosion,

- o Air Contamination,
- o Inability to surface/stay submerged,
- o Collision,
- o Passenger/crew injury, or
- o Inability to rescue the submersible.

The Preliminary Hazard Analysis (PHA) presented in Appendix C of this document identifies more than 140 potential hazards and almost 500 potential causes associated with the 30 subsystems of the passenger carrying submersible operation. Selected hazards are briefly reviewed below. Appendix C should be referred to for additional details.

4.2.2.1 Submersible

A. Hull

Examples of identified hazards associated with the pressure hull which could result in flooding include implosion/failure and leakage. Leakage at hull penetrations, (electrical, mechanical, and piping), viewports, and hatches, though time dependent, could also result in flooding.

B. Ship Control

Hazards related to ballast/trim which could impact on the ability to surface or remain submerged (the latter is important to avoid collision in certain cases) include malfunction or failure of high pressure air tanks and piping, descending below certified test depth, or the inability to control the ascent/decent.

Ballast/trim hazards also include instability while on the surface or submerged, and inability to compensate for the weight of passengers. These hazards could result in passengers falling overboard or down ladders, the submersible rolling, taking on excessive trim angle, or flooding through hatches while loading passengers.

Lack of or loss of manual or automatic piloting controls (including depth gauge, compass, gyro, trim weight, rudder control, etc.) necessary to accurately steer the submersible could result in collision.

Propulsion and maneuvering hazards concern the inability of the submersible to move vertically, forward and aft, or port and starboard. This inability to maneuver could result in collision with obstacles, inability to surface/ remain submerged, or lack of movement necessary to escape entanglement.

C. Systems

Hazards such as insufficient air pressurization, or over-pressurization could result in ballast/trim problems including inability to surface or submerge.

Insufficient hydraulic system pressure could result in loss of steering leading to a collision or inability to jettison weight to surface. Hydraulic fluid leakage could also result in passenger falls, air contamination or fire, as well as collision or inability to jettison weight.

A major electrical hazard is the loss of electrical power to life support systems, propulsion, lighting, ballast/trim controls, etc. This lack of power could result in collision, air contamination, or inability to surface/submerge. Another electrical hazard of particular concern is the battery itself. A battery explosion, generation of gases such as stibine, hydrogen, chlorine or arsine, and lead battery acid leakage, could result in fire or air contamination.

Interior and exterior lighting hazards include inadequate lighting levels or the complete loss of lighting. This could result in insufficient visibility levels necessary for safe piloting during underwater or surface operation and could also result in collision or passenger falls.

Communication between the submersible and surface vessels is vital to the safe operation of the submersible. Communication problems involving the submersible underwater telephone or VHF radio could interfere with safe operations and could result in collision. Limited visibility due to the position of the pilot control console makes the pilot dependent on the continuous communication with the surface support vessel to avoid collision with the support vessel or other surface craft. In addition, if air contamination, fire, or flooding occurs, surface support vessel personnel can advise the submersible crew, take emergency action and/or inform shore facilities.

Loss of oxygen supply and buildup of CO_2, are potential life support hazards which could result in air contamination. Air contamination could also result from inadequate air circulation, loss of temperature/humidity control, or refrigerant or oil leakage. Under-pressurization of the cabin interior may make it impossible to open hatches and evacuate the submersible. Over-pressurization of the cabin interior could result in passenger inner ear injury.

Certain submersible subsystems may have an impact on whether the occurrence of certain hazards are exacerbated or their effects are controlled. Failure to detect toxic or flammable gas, water leakage, or ignition/smoke are hazards which could result in air contamination, flooding, and fire. Another hazard could include the inability to pump out quantities of water resulting from leakage/flooding. Due to the confined area of the submersible cabin interior, and the underwater operation, it is necessary to extinguish fires immediately using an extinguishing agent which does not itself cause air contamination. The inability to surface by rapidly blowing the ballast tanks or releasing jettison weight could prevent the submersible from returning to the surface where fire fighting or medical assistance could be obtained. If the submersible is unable to surface for an extended period of time, the lack of emergency supplies of oxygen or CO_2 absorbent powder may result in air contamination.

The lack of an emergency power supply to vital systems such as communications, propulsion, lighting, and air blowers and fans could result in collision, inability to surface, air contamination, etc. Should passengers fall overboard, or need to evacuate the sub, the lack of flotation devices (i.e., life jackets, buoyant cushions, etc.) could result in passenger drowning. Finally, the submersible could be unable to surface, lose communications with, and thus become isolated from the surface support vessel. The absence of a locating device (i.e., marker buoy, sonar) could prevent rescuers from locating the submersible.

4.2.2.2 Surface/Shore

A. Surface Support Vessel

A collision could result if the surface support vessel loses visual sighting and/or surface or underwater communications with the submersible. If the surface support

vessel fails to keep the immediate area of the dive site clear or at least provide warning to other surface craft, a collision could occur. The lack of flotation devices could result in passenger drowning if passengers fall overboard or need to evacuate from the submersible into the water.

B. Passenger Taxi Vessel

A particular hazard concerns the direct transfer of passengers between the passenger taxi vessel and the submersible at the dive site. Depending on the transfer means, level, or the gap between the vessel decks, passengers could fall between the two vessels and be crushed, or fall overboard and drown.

C. Shore Facilities

Uneven or slick docking or gangway facilities for boarding passengers either to the passenger taxi vessel or directly to the submersible could result in a casualty from falling or drowning. Maintenance personnel may not have adequate access to submersible equipment to perform required maintenance. This could lead to equipment problems, which could result in flooding, air contamination, etc. Maintenance personnel could also be injured if "good housekeeping" is not practiced at maintenance facilities, or if hydrogen gas reaches critical levels during battery charging.

In the event that the submersible is unable to surface, the lack of emergency equipment, such as a lift crane, cable winch assembly, Remotely Operated Vehicles (ROV) or attachable flotation device could prevent passenger rescue.

4.2.2.3 General

A. Documentation

Undesired events such as flooding, air contamination, collision, fire, etc., could result if proper procedures are not available or not followed during passenger transfer, normal operation of the submersible (including operation of the life support equipment), and maintenance. Lack of or incomplete recordkeeping to ensure that the operations and maintenance procedures are actually carried out could also permit hazards to exist.

The absence of or inadequate emergency planning and/or specific emergency procedures to follow in the event of emergency situations could aggravate hazardous conditions and compound the difficulty of rescuing passengers.

B. People

Qualifications, training, and manning levels are major hazard areas relating to the submersible and other vessel and maintenance personnel. For example, the lack of qualifications and experience could prevent or hinder personnel from carrying out the responsibilities and duties necessary for the safe operation of the submersible. The lack of or incomplete training could lead to incorrect decisions or actions during normal or emergency operations. Inadequate numbers of personnel could also result in problems transferring passengers between vessels, assisting passengers in entering the submersible or otherwise affect the safety of the submersible vessel.

There are a number of hazards which passengers may contribute to or create. For example, a passenger may panic because of claustrophobia or require medical attention. Passengers could also deliberately reach out or accidentally brush against submersible equipment controls. Slips and falls could result from passengers wearing footwear which catches on the deck or ladder or makes movement unsteady. Passengers could carry firearms or other dangerous items aboard, or release toxic or pressurized gases, leading to fire or air contamination. If passengers do not know how to swim, emergency evacuation from the submersible into the water may result in drowning if there is no means of rescue.

C. Environment

The weather and marine conditions at the submersible dive site can present hazards during operations. A sudden rainstorm or fog can reduce visibility. High wind can affect the sea dynamics in terms of wave action and sea state resulting in flooding through open hatches and potential passenger falls during loading/unloading. Strong currents (both subsurface and surface) could affect the steering of the submersible and thus result in collision with another surface vessel or underwater obstacle. The current could also cause undesirable separations from the surface support vessel.

Depending on the underwater terrain and contour (i,e., overhangs, narrow sea canyon walls, etc.), a collision or grounding could result. If the submersible drifts or becomes lost, a sharp drop in sea bed slope near the dive site could permit the submersible to descend below its certified depth. Decreased buoyancy as a result of the increase in depth pressure could result in the inability to surface. Water leakage and the inability to operate controls could also occur. The depth could also impact on the ability of a diver to assist the submersible or could prevent a crane from being able to lift it to the surface for rescue.

Hazards such as cables, shipwrecks, or sea plant growth could result in entanglement. Aggressive marine life could attack the submersible, panicking passengers, or damaging equipment. An abandoned pressure vessel or abandoned explosive could, if not identified and removed from the site, explode and damage the submersible preventing it from surfacing.

A sudden disturbance of the sea bed bottom could result in loss of visibility and increase the possibility of collision. A sudden change in water temperature could result in sudden loss of control or ascent/descent of the submersible.

The materials which comprise the interior of the submersible cabin could present fire safety hazards to passengers. In the event of a fire, the flammability and smoke or toxic gas emission characteristics of seats, wall panels, wire and cabling insulation, etc., could contribute to the rapid spread of fire or air contamination.

Sharp objects or edges, low aisle height, or slick cabin floors could result in passenger injury and falls. A steep vertical cant of the ladder, lack of railing or slick surface of the rungs could result in passenger unsteadiness and a fall. If not stowed securely, the access ladder could fall and result in passenger injury.

4.3 FAULT TREE ANALYSIS (FTA)

A fault tree is a graphical representation of the relationship between certain specific events and an ultimate undesired event.

FTA is a deductive analysis technique which uses the top down approach (what and/or why did a particular event happen) to determine the possible causes of an undesired event or system failure.

Fault tree analysis was chosen as one of the principal tools for identifying hazards because it is a systematic method of analyzing the complex series of events which occur during an accident. Each event or sequence of events can also be examined to identify appropriate countermeasures. Fault tree diagrams can and should be used in the following manner:

- As an educational tool to fully explain how an accident occurs and all the contributing factors,
- As an aid in developing vessel procurement specifications,
- As an aid or checklist for the vessel designer,
- As an aid in developing vessel preventive maintenance, repair and operational practices, and
- As an aid in developing emergency response and evacuation procedures.

4.3.1 Fault Tree Development

A typical fault tree diagram is constructed as follows. A particular undesired event is selected. This head undesired event is the event whose occurrence must be minimized or prevented. Primary undesired events, and their interactions and causes, leading to the undesired head event are then examined and broken down into secondary undesired events and causes. This reverse reasoning process continues until there is either insufficient information or an event is not considered significant enough for further analysis. Various symbols are used to represent the relationship between certain specific events and the ultimate undesired event (see Figure 4-3). An example of a simple fault tree for the undesired event "Fire " is illustrated in Figure 4-4. Fuel, oxygen, and heat (ignition source) are all necessary for the fire event to occur, hence the presence of the "And" gate; if one is missing, the fire cannot occur. In contrast, the use of an "Or" gate would indicate that only one of any of the three causes: fuel or oxygen or heat, would be required for a fire to occur.

A review of the available literature, hazard scenarios described in Appendix A, and the generic checklist contained in Appendix B; and discussions with persons knowledgeable about submersible equipment and operations. were used to assist in the development of the fault tree diagrams.

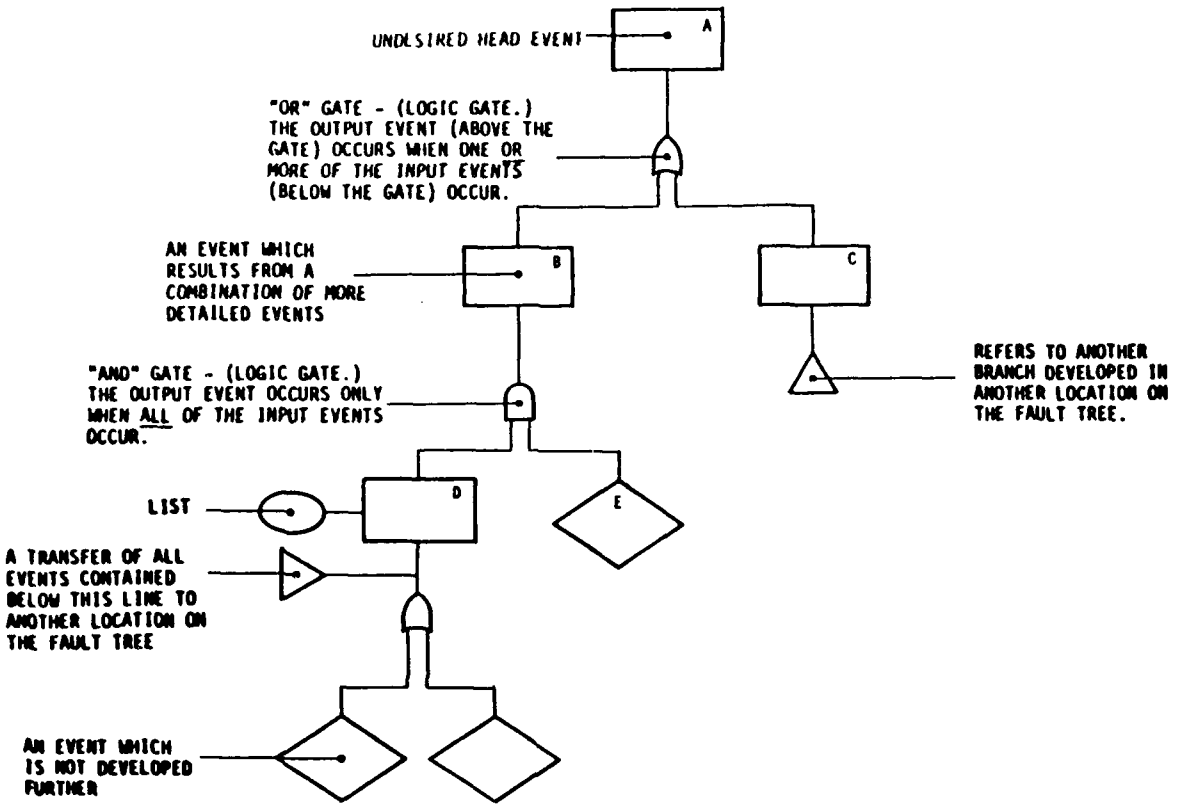


FIGURE 4-3. FAULT TREE SYMBOLS

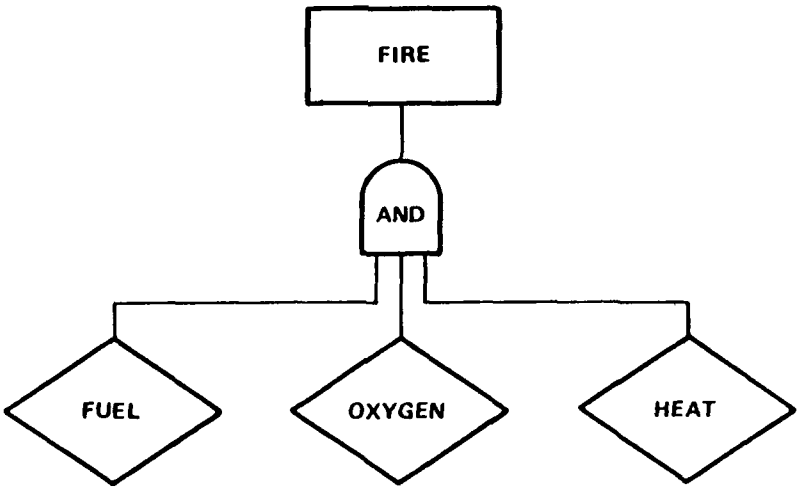


FIGURE 4-4. FIRE FAULT TREE EXAMPLE

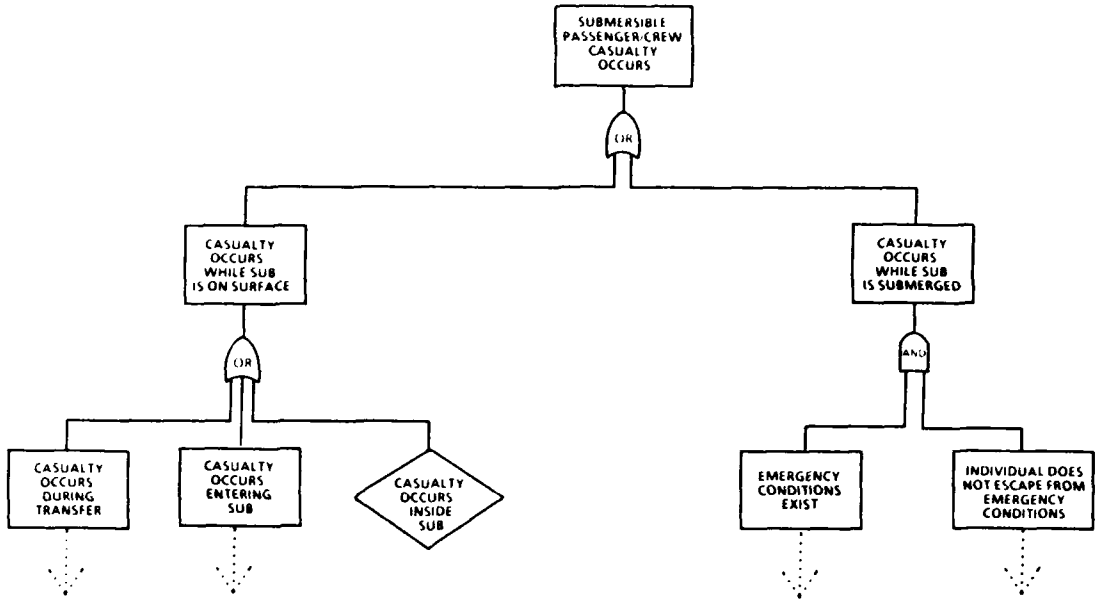


FIGURE 4-5. SUBMERSIBLE PASSENGER/CREW CASUALTY OCCURS FAULT TREE

The qualitative fault trees developed for this report provide overall pictorial diagrams leading to the head undesired event: "Submersible Passenger/Crew Casualty Occurs," (see Figure 4-5). This casualty could occur either while the submersible is on the surface or while it is submerged. The surface casualty could occur either during transfer, entering the submersible, or inside the submersible. To have a casualty while the submersible is submerged, two events must both occur. First, an emergency condition must exist, and second, the individual must be unable to escape from the emergency.

Emergency conditions are undesired events and include conditions such as flooding, air contamination or fire, inability of the submersible to ascend/descend, collision, sub isolation, and illness/injury. Each of these undesired events is examined from the point where the condition occurs and the condition is not being controlled. The main branch leading to the "Individual does not Escape from Emergency Conditions" focuses on the causes why the individual does not escape from the sub or why the individual is not rescued from the sub.

A summary of the undesirable top level events is listed in Tables 4-1 and 4-2. The complete fault tree diagrams are contained in Appendix D.

TABLE 4-1. SUMMARY OF UNDESIRABLE EVENTS - CASUALTY OCCURS WHILE SUBMERSIBLE IS ON SURFACE

CASUALTY OCCURS DURING TRANSFER

INDIVIDUAL FALLS

- o Individual Falls on Deck
- o Individual Falls Overboard
- o Individual Swept Overboard

INDIVIDUAL IS NOT RESTRAINED OR ASSISTED

CASUALTY OCCURS ENTERING SUB

INDIVIDUAL FALLS

- o Individual Falls from Ladder
- o Individual Hits Head

INDIVIDUAL IS NOT RESTRAINED OR ASSISTED

TABLE 4-2. SUMMARY OF UNDESIRABLE EVENTS - CASUALTY OCCURS WHILE SUBMERSIBLE IS SUBMERGED

EMERGENCY CONDITIONS EXIST

HAZARDOUS CONDITIONS ARE PRESENT

- o Flooding Conditions Exist
  - Flooding Occurs
  - Flooding is not Controlled
- o Air Contamination Conditions Exist
  - Toxic Gas Buildup Occurs
  - Toxic Gas is not Controlled
- o Fire/Smoke Conditions Exist
  - Fire/Smoke Occurs
  - Fire/Smoke is not Controlled

POWER FAILURE

SUB CANNOT ASCEND/DESCEND

- o Sub is Unable to Ascend/Descend
- o Attempt by Sub to Ascend/Descend Fails

COLLISION OCCURS

- o Collision Occurs Between Sub and Other Vessel
- o Collision Occurs Between Sub and Obstacle

SUB IS ISOLATED FROM SURFACE SUPPORT VESSEL

ILLNESS/INJURY OCCURS

INDIVIDUAL DOES NOT ESCAPE FROM EMERGENCY CONDITIONS

PASSENGER/CREW CANNOT LEAVE SUB

- o Passenger/Crew Cannot Escape from Sub
  - Individual does not Take Timely Action
  - Egress is Impossible
- o Individual is not Rescued from Sub
  - Assistance is Unavailable
  - Assistance is Unable to Take Timely Action

INDIVIDUAL DROWNS AFTER LEAVING SUB

4.3.2 Fault Tree Findings

The undesired events depicted in the fault tree diagrams closely parallel those identified in the hazard scenarios and the PHA. While the causes of the undesired events in the fault trees are identified more fully than in the scenarios, the causes are not covered to the extent that they are listed in the PHA. This is because the emphasis of the fault tree diagrams is to identify and present the progression and combination of potential events, hazards, and causes which could lead to a passenger submersible casualty. Moreover, the format of the fault tree diagrams illustrates the importance of the relationships between the events.

A review of the fault tree diagrams shows that a passenger/crew casualty could occur either while the submersible is on the surface or while it is submerged. This is an important point for two reasons. First, certain events and hazards which could result in a casualty could occur while the submersible is on the surface, particularly passenger falls. This perspective has thus been expanded beyond the more obvious or dramatic types of problems which could occur while the submersible is submerged. As a result, the characteristics of the passenger submersible operation which make up this "dual aspect of operation" are addressed. Second, both the severity of the potential hazard and the necessary level of emergency response effort will vary widely depending on the location of the submersible during an emergency.

While the prevention of as many hazards as practical is desirable from a safety standpoint, certain hazards are either inherent to the operation of the system or cannot be completely eliminated. Thus, a significant element of the fault trees is the indication of "And" gates to signify a double point hazard at high levels of the fault tree diagram. That is, an undesired event exists and it is not controlled or responded to in some way. As an example, a passenger falls, and is not restrained or assisted. Again, flooding conditions exist because both flooding occurs and the flooding is not controlled. Passenger falls, flooding, air contamination, fire, and and inability of the submersible to surface are the events which were extensively developed to illustrate this double point hazard concept. The branch of the fault tree illustrating fire/smoke suppression/containment was considered a particularly important control area to examine because of the confined environment of the submersible.

The fault tree diagrams depicting the actions and facilities pertaining to passenger escape and rescue from emergency conditions illustrate some key points relating to passenger safety. Proper advance planning, provision of pre-determined emergency procedures, adequate and frequent training, and availability of emergency equipment all contribute greatly to the success of swift, effective emergency response operations.

5. RISK ASSESSMENT

The results of the hazard identification process have been described in Section 4. This process resulted in the identification of several typical undesired events that may result in a submersible passenger or crew casualty. These undesired events are as follows:

- o Flooding/leakage,
- o Collision,
- o Fire/explosion,
- o Air contamination,
- o Inability to ascend or descend,
- o Unable to rescue submersible, and
- o Vessel isolation.

Associated with each of these undesired events are potential hazards and causal factors. In total, more than 140 hazards and almost 500 causal factors were identified. Each of the undesired events could, if the appropriate countermeasure is not taken, result in a passenger/crew casualty or loss of the submersible. Furthermore, each undesired event may occur or be a result of one or more hazards and causal effects that involve one or more of the submersible systems or subsystems. Within the PHA, the hazards and causal factors were identified for the elements, systems, and subsystems of the passenger submersible operation. To adequately address the safety of submersibles requires that each system and subsystem be examined and the appropriate action taken to mitigate the occurrence of the undesired event.

Due to the large number of hazards and causal factors, it was not possible to assess in detail each of the potential hazards and causal factors identified in the PHA. The hazard assessment values contained in the PHA are of a subjective nature in the absence of quantitative data. As operating experience is accumulated, the assigned hazard assessment values can be adjusted to more realistically reflect the severity and probability of the hazards. The following sections address the assessment of the undesired events. The results of this assessment provide guidance on the safety needs of the individual submersible systems and subsystems.

5.1 UNDESIRED EVENT SEVERITY AND PROBABILITY ESTIMATES

As a means of establishing an understanding of the risk associated with submersible operations and the countermeasures that may be employed to address those risks, the undesired events have been assessed for severity and probability of occurrence. This effort is subjective but can provide an indication of which undesired events pose the largest threat to passenger casualties and submersible loss. Understanding this will assist in determining which of the available countermeasures may be employed to address those threats.

To assist in establishing event severity and probability of occurrence categories, the hazard categories presented in MIL-STD- 882B have been modified to address the specific undesired events associated with passenger carrying submersibles. Figures 5-1 and 5-2 present these modified severity and probability categories.

5.1.1 Severity of Undesired Event

The severity or magnitude of the consequences of an undesired event will depend on the following factors: first, when the event occurs in the operating cycle (surface, submerged, etc.); second, whether the event is time dependent (leakage vs. flooding, etc.) and finally, whether it can be controlled (pumping). For the purpose of the assessment presented here, the number of undesired events has been expanded to include several intermediate events and the operating cycle has been defined as follows:

- Passenger transfer to submersible,
- Pre-dive just before closing hatch to descend,
- Descending and ascending, and
- Submerged touring.

Estimates of the severity associated with these undesired events which could involve the submersible operation and its passengers/crew are contained in Table 5-1. It is recognized that the severity of the individual event may vary considerably. However, for the purposes of this study, the most severe consequence has been postulated.

CATEGORY	SEVERITY	CHARACTERISTICS
I	CATASTROPHE	Death to passenger or employee, loss of submersible.
II	CRITICAL	Severe injury to passenger or employee, hazard or single point failure may lead to catastrophe if action is not taken to control situation or rescue individual. Critical systems are involved and submersible unable to surface. Time of response is important in preventing death or submersible loss.
III	MARGINAL	Minor injury not requiring hospitalization or the hazard present does not by itself threaten the safety of the submersible or passengers. No critical systems are disabled, but could be if additional failure(s)/ malfunction(s) /hazard(s) occur.
IV	NEGLIGIBLE	Less than minor injury. Does not impair any of the critical systems.

FIGURE 5-1. UNDESIRED EVENT SEVERITY CATEGORIES

CATEGORY	LEVEL	SPECIFIC EVENT
A	FREQUENT	Not an unusual event, could occur several times in annual operations
B	PROBABLE	Event could occur several times in the lifetime of the submersible.
C	OCCASIONAL	Expected to occur at least once in the lifetime of the submersible.
D	REMOTE	Event is unlikely to occur during the lifetime of the submersible
E	IMPROBABLE	Event is so unlikely that it is not expected to occur in the lifetime of the submersible.

ASSUMPTION:

Event is estimated to occur as a function of number of dives, operating hours, and the number of patrons carried. Sub will dive an average of 5 times a day, 300 days a year.

FIGURE 5-2. UNDESIRED EVENT PROBABILITY CATEGORIES

TABLE 5-1. UNDESIRED EVENT SEVERITY ESTIMATES

EVENT DESCRIPTION	OPERATIONAL PHASES INVOLVING PASSENGERS			
	Passenger Transfer	Pre - Dive	Sub Descends/Ascends	Sub Tours
Flooding	II	II	I	I
Leakage	III	III	II	II
Collision	II	II	II	II
Fire/Explosion	II	II	I	I
Air Contamination	NA	III	II	II
Passenger Illness/Injury	II	II	II	II
Passenger falls in water	II	NA	NA	NA
Passenger falls on deck	III	NA	NA	NA
Inability of sub to surface	NA	NA	II	II
Inability to rescue sub	NA	NA	NA	I
Excessive Pitch or Roll	II	II	II	II
Sub isolated	NA	NA	III	III

N/A Not applicable

In operational phases such as passenger transfer and pre-dive, the severity or effect of certain events on a passenger or crewmember may be less than when submerged. This is because the passenger/crew may evacuate the emergency situation more readily during passenger transfer and pre-dive operations. Hence, in most instances, the undesired event may be categorized as "Critical" or "Marginal."

In contrast to the surface operations, the submersible may, during descent/ascent or touring, have insufficient time to surface. Because passengers/crew may thus be unable to evacuate emergency conditions, the undesired event may result in more severe consequences. When this situation is present, the severity of the undesired event is deemed to be a Category I "Catastrophe." Although the severity or consequences of an event could be great, the probability of an undesired event occurring could be quite small. This is because both the emergency condition must occur and the passenger/crew cannot evacuate that emergency condition in time to prevent the occurrence of the casualty.

5.1.2 Probability of Occurrence of Undesired Event

To establish, in absolute terms, the probability that an event will occur, requires a calculation based on previous experience. This calculation should take into consideration that the event may have occurred or been reported to occur a certain number of times. For the passenger carrying submersible, no publicly available data base exists from which to calculate the probability of occurrence of an undesired event. Operating experience and data for military submarines (especially nuclear submarines) is classified and operating experience and data on industrial/research submersibles is limited. Data on incidents and near misses is limited for military submarines and industrial/research submersibles and cannot be used to adequately calculate probabilities. To provide an indication of the relative probability of occurrence of the undesired events, the Hazard Probability Matrix of MIL-STD-882B has been modified as shown in Figure 5-2. The term "several" is intended to connote that an event may occur 10 times in a designated period (annual, lifetime, etc.). Table 5-2 presents an estimate of the probability of occurrence of the undesired events. These estimates are subjective and as shown in the fault trees in Appendix D, require that both the hazard and the inability or failure to control the undesired event must occur be present for the undesired event to result. As an example, for a fire/smoke condition to exist, the fire must occur and the fire is not controlled or contained.

TABLE 5-2. UNDESIRED EVENT PROBABILITY ESTIMATES

EVENT DESCRIPTION	OPERATIONAL PHASES INVOLVING PASSENGERS			
	Passenger Transfer	Pre - Dive	Sub Descends/Ascends	Sub Tours
Flooding	C	C	D	D
Leakage	NA	NA	C	C
Collision	C	C	C	C
Fire/Explosion	D	D	D	D
Air Contamination	NA	E	C	C
Passenger Illness/Injury	C	C	D	D
Passenger falls in water	B	NA	NA	NA
Passenger falls on deck	B	NA	NA	NA
Inability of sub to surface	NA	NA	D	D
Inability to rescue sub	NA	NA	NA	D
Excessive Pitch or Roll	D	D	D	E
Sub isolated	NA	NA	D	D

N/A Not applicable

5.2 RISK ASSESSMENT ESTIMATES

The risk associated with an undesired event is the product of the severity of the event and the probability of occurrence of that event. For the purpose of this assessment, the worst estimated severity value has been assigned to the undesired event. As shown in Table 5-1, the severities assigned to the undesired events were primarily of a critical and catastrophic nature. In contrast, the estimated levels assigned in Table 5-2 indicate that the probability of occurrence of such events would be uncommon.

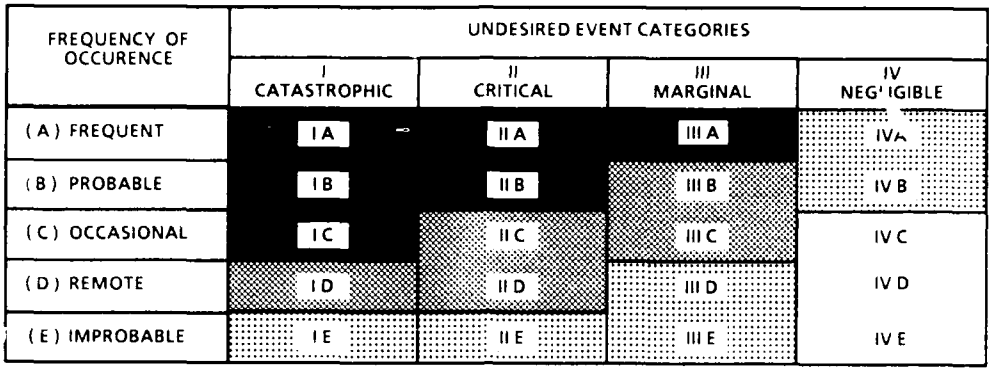
Although, in most cases, the probability of the undesired events is estimated to be low, the potential severity of certain undesired events listed requires that some type of action be taken to minimize the risk. The risk assessment estimates shown in Figure 5-3 can assist in the decision-making process to determine whether individual submersible system or subsystem hazards should be eliminated, controlled, or accepted to reduce the occurrence of the particular undesired event.

To evaluate these undesired events, the Risk Assessment Matrix shown in Figure 5-4 (modified from MIL-STD-882B) was used. The undesired event, Passenger Falls in Water (During Transfer), was assigned a IIB (Critical/Probable) risk index value. Accordingly, the Matrix indicates that this is inherently "Unacceptable" and therefore action must be taken to eliminate or control the hazards associated with this event. Action should also be taken to minimize the potential risk of undesired events with risk index values of ID, IIC, IID, IIE, and IIIB. Section 6 identifies and presents 10 general areas of countermeasures that may be employed to reduce the potential risk of the undesired events.

TABLE 5-3. RISK ASSESSMENT ESTIMATES

EVENT DESCRIPTION	OPERATIONAL PHASES INVOLVING PASSENGERS			
	Passenger Transfer	Pre - Dive	Sub Descends/Ascends	Sub Tours
Flooding	IIC	IIC	ID	ID
Leakage	NA	NA	IIC	IIC
Collision	IIC	IIC	IIC	IIC
Fire/Explosion	IID	IID	ID	ID
Air Contamination	NA	IIIE	IIC	IIC
Passenger Illness/Injury	IIC	IIC	IID	IID
Passenger falls in water	IIB	NA	NA	NA
Passenger falls on deck	IIIB	NA	NA	NA
Inability of sub to surface	NA	NA	IID	IID
Inability to rescue sub	NA	NA	NA	ID
Excessive Pitch or Roll	IID	IID	IID	IIE
Sub isolated	NA	NA	IIID	IIID

N/A Not applicable



RISK INDEX

IA, IB, IC, IIA, IIB, IIIA		UNACCEPTABLE
ID, IIC, IID, IIIB, IIIC		UNACCEPTABLE (MANAGEMENT DECISION REQUIRED)
IE, IIE, IIID, IIIE, IVA, IVB		ACCEPTABLE WITH REVIEW BY MANAGEMENT
IVC, IVD, IVE		ACCEPTABLE WITHOUT REVIEW

FIGURE 5-3. RISK ASSESSMENT MATRIX

6. RISK REDUCTION COUNTERMEASURE IDENTIFICATION

The hazard scenarios presented in Appendix A provide an insight into how typical emergency situations may arise during the operation of a passenger carrying submersible. Each of the undesired events identified in the scenarios, the PHA and the fault trees were assessed for severity and probability of occurrence and the results are presented in Section 5. For the majority of the undesired events, the severity was estimated to be "Critical" or "Catastrophe." The probability of occurrence, with the exception of passenger falling accidents, ("Probable"), was estimated to be "Occasional," "Remote" or "Improbable." In terms of the acceptance criteria presented in Figure 5-4, the severity of the majority of the undesired events does indicate that certain actions should be taken to minimize both the consequences and probability of occurrence.

Actions to be taken to minimize the potential risk are termed countermeasures. For the purpose of this study, a countermeasure may be defined as any action or series of actions that may be taken to reduce the risk of a casualty associated with the operation of a passenger carrying submersible. The risk reduction may be accomplished by countermeasures intended to eliminate the occurrence or minimize the effect of the undesired event. Elimination or prevention of the occurrence of the undesired event is obviously preferable but not always possible. Recognizing this, it is important to minimize the severity or effects of the specific undesired event. This may be accomplished by reducing the expected severity of the event and/or enhancing the response to the occurrence of the event. The majority of risk reduction countermeasures described below emphasize the prevention of the occurrence of the event (primary countermeasure) with the response or secondary countermeasures comprising the remainder of the countermeasures.

During the conduct of the PHA, recommendations for countermeasures were identified for the hazards and causal factors identified in each element of the submersible system and subsystem.

The recommendations for corrective actions presented in the PHA worksheets describe the method selected to eliminate the causes or minimize the effects of each hazard. One or more recommendations are provided for each hazard-cause identified within the individual submersible systems and subsystems. Many

recommendations are based on existing codes, standards, and guidelines. However, a number of recommendations are either based on information which may need updating or are not currently addressed at all by existing references. At times, reference sources recommend different criteria (i.e., percent of CO_2 permitted); in such cases, all criteria are presented.

The following sections present a summary of the countermeasures identified in the PHA. For the detailed identification of individual system and subsystem countermeasures that may be employed to mitigate the undesired event, the reader is referred to the PHA in Appendix C.

6.1 DESIGN COUNTERMEASURES

During the conduct of the Preliminary Hazard Analysis (PHA), it was found that most hazards resulting from design or fabrication of submersibles can be avoided by following existing codes, standards, regulations, and guidelines. However, it should be noted that the existing codes and standards were:

- *Developed for application to surface vessels (46 CFR and 33 CFR), and/or*
- Developed for application to submersibles used by industry, scientific research and the military (ABS, PVHO and NAVMAT P9290).

The ABS Rules[8] and the ASME /PVHO Safety Standard[9] contain design requirements that are applicable for most of the submersible subsystems and equipment.

In addition, the current Coast Guard submersible guidelines, plan review and inspection process, and CFR regulations also address many of the subsystem and equipment hazards from a design standpoint The Coast Guard is also preparing a Navigation and Vessel Inspection Circular which will provide guidance for certifying passenger carrying submersibles used in the tourist trade.

Redundant or backup systems for safety critical items are recommended in several instances in the PHA. Although backup systems are expensive and often complex, it is believed that such systems are likely to be the best way to reduce the probability of certain undesired events. It may, however, be determined during design that other methods of controlling hazards may be more appropriate. Also, it may be determined during design that backup systems are required to reduce the

probability of additional hazards. The decision regarding which systems require back-up has been based on the information available at the time the analysis was completed.

Fire safety of materials for the confined interior spaces of the submersible was identified as a major hazard of concern. The existing references do not consider the negative effects of the flame spread and smoke emission characteristics of interior materials. The Federal Aviation Administration[10], Urban Mass Transportation Administration[11], and the Federal Railroad Administration[12], have developed regulations and guidelines for passenger interior materials for airplanes, transit cars and intercity rail cars. The criteria in these regulations and guidelines could also be applied to passenger carrying submersibles to improve fire safety.

The additional submersible safety issues identified below should be explored by the Coast Guard in further detail. (In some cases, certain items such as the hatch seal design are covered by only the NAVMAT P-9290.[13]).

- Hatch seal design to prevent leakage,
- Penetration design to include separate safety(sea) valves and cutoffs to prevent or control leakage,
- Viewport protection to prevent internal or external damage,
- Propulsion and maneuvering capability to ensure maneuverability, under all conditions (such as entanglement),
- Immediate automatic activation of emergency lighting upon electrical power loss,
- Battery protection against explosion,
- Redundant communication ability, both while submerged and on the surface, and
- Provision of alarms to indicate air pressure loss, water or hydraulic fluid leakage, fire/smoke, air quality (oxygen supply, CO_2 level),

Other serious safety issues identified during the PHA, which do not appear to be adequately covered by existing codes, standards, or regulations, are associated with training, operations, maintenance, and documentation. As indicated in the PHA, hazards in these areas are characterized by a high incidence of human interaction. The following sections of general countermeasures are the result of a comprehensive review of the PHA by a series of knowledgeable individuals. These countermeasures reflect what those individuals believe are the most serious safety related issues which should be addressed.

6.2 TESTING AND INSPECTION COUNTERMEASURES

A testing and acceptance program should be implemented to determine if all safety-related systems aboard the submersible meet operational requirements. All test procedures and results of the tests should be documented and provided to the USCG. These tests should include the following:

- o Subsystem Test (i.e., life support, electrical, etc.),
- o System Test (i.e., hull, etc.),
- o Operational Tests,
- o Acceptance Tests, and
- o Periodic Emergency System Tests.

Each submersible should be certified by the Coast Guard, prior to initiating operations with passengers. Builders trials should demonstrate that the operating characteristics of the submersible safety systems and subsystems match the parameters specified in the design. Sea trials should be conducted only after all discrepancies identified during the early testing phases have been resolved to the satisfaction of the USCG. Certification dives should be conducted in the environment where the submersible will operate.

Periodic inspections by the submersible operators and guidelines for these inspections should be prepared. Inspections should be conducted during the following phases: Manufacture, Testing, and Operation. Reports should be prepared and submitted to the USCG for approval.

6.3 CONFIGURATION MANAGEMENT COUNTERMEASURES

A configuration management program should be implemented to ensure that design, development, and operational changes to safety-related systems and subsystems for the submersible are subjected to strict configuration control. These documents, should as a minimum, include Training Materials, Test Documentation, System Maintenance Documents, Operating Procedures, and Emergency Procedures.

6.4 OPERATIONAL COUNTERMEASURES

There are no guidelines or regulations which require the submersible manufacturers to define the operational parameters for specific submersibles. Design, fabrication, testing, acceptance, and operations of safety-related systems and subsystems could vary considerably depending on the submersible's intended mission. Different potential missions mentioned in the available literature include passenger ferry operations, deep submergence dives, shallow dives in shallow water (less than 200 feet deep), and shallow dives in deep water (water depth up to several thousand feet deep). The intended operating parameters of each submersible are currently approved by the USCG. Countermeasures should be established which address the following:

- Guidelines and regulations requiring development and documentation for operating procedures,
- Guidelines for passenger indoctrination, and
- Guidelines for the following operations:
  - Deep submergence,
  - Shallow dives in deep water,
  - Operations in colder climates or cold water.

6.5 TRAINING COUNTERMEASURES

Training programs should be developed for all safety-related phases of the tourist submersible operation. Guidelines, which include minimum qualifications for applicants in critical positions, should be established. A training path leading to certification should be clearly defined, as well as measurable goals and objectives for each aspect of the training. The training guidelines prepared by the Deep Submersible Pilots Association[14] could be adapted for passenger submersible personnel.

The training program should clearly represent a systems approach to training and include, but not be limited to:

- A training assessment phase to determine the training needs and to derive training objectives,
- A training development phase to select training methods and to develop the training courses,

- o A training phase during which training is conducted, and
- o An evaluation and feedback phase which should continue throughout the submersible system life cycle. This feedback can assist in determining if the training is appropriate for the tasks being performed, and to assure that any operational or equipment changes are reflected in the curricula.

6.6 MAINTENANCE COUNTERMEASURES

Maintenance countermeasures include the development of maintenance procedures and management documentation for all safety-related systems and subsystems. This includes routine maintenance procedures and preventive maintenance procedures and plans. These should be developed during the design and development phase and approved by the USCG. In addition, audits or periodic inspections should be conducted to assure that approved procedures are being implemented and preventative maintenance is being performed.

Maintenance documentation should include requirements for failure analysis, quality assurance standards for critical repairs, guidelines for parts substitution, guidelines for ready spares stock, inspection and testing requirements, and preventative maintenance record requirements. Navy documentation which may be applicable includes all 4790 maintenance series instructions[15,16,17], and the MIL-P-24534A, military specification for maintenance[18].

Operations conducted in areas remote from the submersible system or subsystem manufacturers can create numerous logistics-related problems, many of which may result in safety problems, including the following:

- o Inability to obtain spare parts quickly resulting in substitution of unapproved parts,
- o Spare parts which have been stored and have exceeded their shelf life,
- o Deterioration of parts due to harsh environments (high humidity, salt air, excessive temperatures), and
- o Inadequate or improper repair and re-use of components.

Quality Assurance (QA) plans should include procedures for acceptance of spares and spare substitution guidelines. All critical repairs should be performed in accordance with strict QA procedures. A logistic support plan should include requirements for failure analysis to be used as an input to determine spares stocks.

6.7 EMERGENCY PREPAREDNESS COUNTERMEASURES

An emergency preparedness plan should be developed to address all aspects of emergency planning and emergency response. This document should, as a minimum, include: emergency operating procedures, procedures for search and rescue, operating emergency equipment, operating in inclement weather, and coordination with other organizations.

6.8 LIFE EXPECTANCY COUNTERMEASURES

A vessel life expectancy or safe number of operating cycles for each submersible hull type should be determined during the design phase. This "safe number of cycles" should be reviewed periodically during the operation of each submersible to determine if the predicted life expectancy is appropriate considering actual experience. Issues to be considered include but are not limited to:

- o Viewport and hatch seals,
- o Hull fatigue,
- o Excessive corrosion,
- o Lack of maintenance,
- o Hull damage (should require immediate recertification), and
- o Repairs to hull penetration (should require acceptance tests).

6.9 RECERTIFICATION OR INSPECTION COUNTERMEASURES

As previously indicated, all submersible safety related systems and subsystems should be periodically inspected by the USCG. Criteria should be developed for determining when (other than after a normal periodic inspection) a submersible should be inspected, or if necessary, recertified. Several incidents which should require re-certification are listed in the previous sub-section. Other incidents which should require recertification, or as a minimum, inspection by the USCG include, but are not limited to:

- o Excursion beyond test depth (should require immediate re-certification),
- o A major change in operating parameters,
- o After a submersible is drydocked,
- o System modifications (engineering changes),

- o Major system replacements,
- o After scheduled overhauls, and
- o After transfer of ownership.

6.10 DEGRADED OPERATION COUNTERMEASURES

As with aircraft, ships, or other transportation systems, submersibles can operate in a degraded mode. Minor malfunctions such as burned-out light bulbs and faulty indications may not jeopardize the safety of the passengers or crew. However, criteria should be developed to clearly indicate which failures or combinations of failures constitute a minor inconvenience, and which failures should result in canceling the dive.

7. EVALUATION OF POTENTIAL COUNTERMEASURES

A total of 10 broad areas of countermeasures were identified and briefly described in Section 6. Within each of these areas, the PHA identifies specific countermeasures that may be applied to the individual submersible subsystems. In several instances within the PHA, more than one countermeasure is identified for a particular subsystem. Furthermore, the individual undesired event may have resulted from: 1) hazards and causal effects contained in one or more subsystems in the same system (within the hull system, flooding may occur from several subsystems); or 2) from hazards and causal effects in different systems (i.e., flooding may also occur in the operating procedures subsystem).

Recognizing that an undesired event may result from one or more sets of hazards and causes in either one system or involving different systems and subsystems, two or more countermeasures may be required to prevent or reduce the occurrence of that undesired event. With this knowledge, it is important that each undesired event be examined and all possible system and subsystem hazards and causal effects be examined to identify countermeasures that will mitigate the undesired event. Having identified all of the countermeasures that may be employed to mitigate an undesired event, selection of the most appropriate countermeasure will be determined by examining the following factors:

- o Effectiveness of Countermeasure
  - Reduce probability of occurrence
  - Reduce severity of event
- o Cost of Implementation
  - Design to eliminate
  - Operation procedures to control
  - Retrofit
- o Enforcement Requirements

These three factors are the primary considerations to be evaluated in selecting the appropriate countermeasure to mitigate an undesired event.

The means by which the results of this system safety analysis may be incorporated in submersible design and operation is through standards published in the Code of

Federal Regulations. (CFR) Development and implementation of safety standards will require a "Regulatory Assessment" to examine the effect the regulations will have on the submersible industry. This "Regulatory Assessment" will establish the costs and benefits associated with the particular selected standards/regulations. A detailed assessment is not possible until the standards or regulations have been drafted. The following sections provide guidance on how the individual factors may be evaluated and assessed.

7.1 EFFECTIVENESS OF COUNTERMEASURES

Evaluation of the effectiveness of a countermeasure requires a judgment on how the implementation of a specific countermeasure will influence the probability of occurrence and severity of the undesired event being addressed. With regard to probability of occurrence, the countermeasure may:

- o Result in no change,
- o Reduce the probability of occurrence of the event, or
- o Totally eliminate the possibility of event occurrence (no event).

In a similar manner, the countermeasure may influence event severity by:

- o No change,
- o Slightly less severe,
- o Totally minimize the effect, or
- o Possibly increase severity.

7.2 COST OF IMPLEMENTATION

The cost incurred in implementing a countermeasure will depend on when in the submersible life cycle the countermeasure is adopted. In general, it is more cost-effective to design in the countermeasure prior to production or operation of the system. Furthermore, the cost will be directly related to the submersible system or subsystem into which the countermeasure is adopted. For example, procedural changes will generally cost less to implement than providing new or modified submersible equipment. The cost associated with the 10 areas of countermeasures identified in Section 6 may be allocated into the following phases of the system life cycle:

- o System design,
- o System fabrication,
- o System testing,
- o System operation,
- o System maintenance, and
- o System retrofit.

Within each of the above phases of the system life cycle, the cost will depend on the following basic cost elements:

- o Materials costs,
- o Labor costs,
- o Training costs,
- o Operating costs, and
- o Downtime costs.

Having established the cost of implementation of a specific countermeasure, the cost must be considered relative to the effectiveness of the countermeasure. For example, the cost associated with a design change early in the system design may be worth the additional cost if that countermeasure will eliminate a hazard.

Labor and materials costs expended in the design and system testing phases should be employed to eliminate hazards in the system. Labor, training, and downtime costs associated with the implementation of a countermeasure during system operation and maintenance are more likely directed at controlling known hazards. This approach is not as desirable or as safe as eliminating the hazard prior to system operation.

7.3 ENFORCEMENT REQUIREMENTS

A secondary cost associated with the implementation of a countermeasure is that of ensuring that the countermeasure has actually been implemented and is operating properly. For example, special operating procedures, warning devices, etc. This requirement for enforcement will require the dedication and the expenditure of Coast Guard resources. Enforcement is an expense that must be borne by the Government and as such will not be discussed in detail. However, this should be evaluated prior to countermeasure selection and implementation.

8. CONCLUSIONS AND RECOMMENDATIONS

After reviewing the results of the system safety analysis of passenger carrying submersibles, the following conclusions and recommendations are provided for consideration.

8.1 CONCLUSIONS

1. The use of submersibles to carry passengers on underwater tours has increased in popularity over the past 5 years and continued commercial growth is anticipated.

2. The Coast Guard has used the contents of 46 CFR, Subchapter T Small Passenger Vessels, and other applicable parts of 46 CFR and 33 CFR, to formulate guidelines used to certify passenger carrying submersibles subject to U.S. jurisdiction. However, many of the requirements contained in the existing Coast Guard statutes and regulations cannot be applied to or are inappropriate for submersibles because they have been developed for surface craft.

3. No loss of life has occurred to date for any of the tourist submersible operations.

4. Data is not readily available which either describes or quantifies actual accidents/incidents or specific hazards involving passenger carrying submersibles currently used in the tourist trade.

5. More than 140 potential hazards and 500 causes were identified during the system safety analysis performed for this study. Unless these hazards are eliminated or controlled, they could result in undesired events which could lead to submersible passenger/crew casualties.

6. While the prevention of as many undesired events and hazards as is practical is desirable from a safety standpoint, certain hazards are either inherent to the operation of the system or cannot be completely eliminated. The fault tree diagrams demonstrate the importance of the interaction of undesired events and their causes. Moreover, the consequences of an undesired event or hazard could be more severe if it is not controlled or responded to in some way.

7. Undesired events which could lead to a passenger casualty include: flooding/leakage, collision, fire/explosion, air contamination, passenger illness/injury, passenger falls in water, passenger falls on deck, submersible is unable to surface, submersible is not rescued, excessive pitch or roll, and submersible isolation. The location of the submersible when the undesired event occurs has a direct impact on the severity of the event and the level of emergency response required.

8. An assessment of the undesired events identified passenger falls during transfer between the taxi vessel and the submersible as a major safety problem in terms of severity (II Critical) and probability of occurrence (B Probable). Although "Unacceptable" as defined by the criteria of the Military Standard:System Safety Program Requirements (MIL-STD 882B)[4], this undesired event cannot be totally eliminated due to the inherent hazard of possible changes in the sea state. Other undesired events were assigned risk values of ID, IIC, IID, IIE, and IIIB (See Table 5-3). These undesired events require further analysis to reduce the level of risk.

9. A number of industry and Navy codes, standards and guidelines exist which address the majority of submersible design safety issues. However, these codes, standards, and guidelines were developed for application to submersibles used by industry, scientific research, and the military. Moreover, these submersibles carry a limited number of personnel, the majority of whom are knowledgeable and experienced with submersible operations.

10 Certain safety issues pertaining to the unique characteristics of submersibles carrying large numbers of tourists (more than 6) have been identified as a result of the system safety analysis. These issues include design, training, operations, maintenance, testing and inspection, configuration management, emergency preparedness, life expectancy, reinspection/recertification, and degraded operations. Countermeasures which address these safety issues are contained in Section 6.

11. Selection of the most appropriate countermeasure to reduce the severity and probability of an undesired event is dependent on three factors: effectiveness, cost of implementation and enforcement requirements.

12. A Quality Assurance and Inspection program is essential to ensure that materials, fabrication, maintenance and operations do not degrade the safety of the submersible.

8.2 RECOMMENDATIONS

1. The Coast Guard should require additional analysis to be performed to further investigate the undesired events assigned the risk values of II B, ID, IIC, IID, IIE, and IIIB (See Table 5-3), in order to identify the appropriate means of controlling the severity and minimizing the probability of occurrence through design, safety devices, warning devices, special procedures, and training, or a combination thereof.

2. The Coast Guard should further explore the following design safety issues specifically for application to passenger carrying submersibles:

   - o Redundancy of safety critical systems,
   - o Fire and smoke characteristics of interior materials such as seating, etc.,
   - o Hatch seal design to prevent leakage,

- o Penetration design to include separate safety (sea) valves and cutoffs to prevent or control leakage,
- o Viewport protection to prevent internal or external damage,
- o Propulsion and maneuvering capability to ensure maneuverability under all hazardous conditions (such as entanglement),
- o Immediate activation of emergency lighting upon electrical power loss,
- o Battery protection against explosion,
- o Redundant communication ability, both while submerged and on the surface, and
- o Provision of alarms to indicate air pressure loss, water or hydraulic fluid leakage, fire/smoke, air quality (Oxygen supply, CO_2 level).

3. The Coast Guard should require that each passenger carrying submersible designer/operator develop a System Safety Program. This program should include a system safety plan and the review process necessary to identify and resolve all single point hazards in safety critical systems and subsystems. This system safety plan should designate the individual responsible for the safety of the submersible and address means of hazard reduction such as training, operations, maintenance, testing and inspection, configuration management, emergency preparedness, life expectancy, reinspection/recertification and degraded operations, to address specific hazards as identified.

4. The Coast Guard should develop and implement requirements which will serve to prevent the occurrence of undesired events or minimize their consequences and/or reduce the probability of occurrence. These requirements should address the general areas of training, operations, maintenance, testing and inspection, configuration management, emergency preparedness, life expectancy, reinspection/recertification and degraded operations, as identified in Section 6 of this report.

5. The Coast Guard should develop criteria for and implement an accident/incident reporting system to identify safety issues and quantify accident trends.

6. The Coast Guard should review and expand, if necessary, the document entitled, "Passenger Carrying Submersible Inspection Book." This document should then be distributed to all appropriate OCMI to provide assistance to Coast Guard personnel in evaluating and certifying local submersible operations.

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16. Naval Sea System Command, Department of the Navy, NAVSEAINST 4790.3B, Policy and Responsibility for Processing Planned Maintenance System (PMS) Technical Feedback Reports (Report Symbol OPNAV 4790-4), June 6, 1985.

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18. Department of the Navy, MIL-P-24534A (NAVY), Military Specification for Planned Maintenance Subsystem: Development of Maintenance Requirements Cards, Maintenance Index Cards, and Associated Documentation, May 7, 1985.

APPENDIX A. HAZARD SCENARIOS

This Appendix describes scenarios in which passenger carrying submersibles could be involved in emergency situations.

SCENARIO DEVELOPMENT

The use of previous operating experience or case studies of past accidents or incidents provides a starting point for identification of the types of emergency situations or "events," which have occurred. From this data, scenarios which reflect the real-world accident experience may then be created. The scenarios contained in this section present the undesired event, causes, and ultimate results in brief narrative form. Passenger carrying submersibles (for the tourist trade) have been operating in the Caribbean for the last 5 years. Because this operating experience (exposure) of passenger carrying submersibles has not resulted in the occurrence of any deaths or serious injuries, it is necessary to review information from other sources to determine the kinds of potential emergency situations which could occur. The scenarios presented here have been derived from the experiences of military submarines and research/industrial submersibles. Although many details of the military experience are classified, Reference 1 provides an excellent insight into peacetime submarine accidents. Insight into emergency situations involving industrial/research submersibles is provided in References 2 and 3. Coast Guard correspondence with submersible companies also highlighted potential scenarios (see Reference 4). (References for this appendix are listed on page A-8.)

Seven typical types of submersible emergency situations presented are categorized as follows:

- Flooding,
- Inability to ascend or descend,
- Fire,
- Collision,
- Air contamination,
- Passenger illness/injury, and
- Sub isolation from surface support vessel

Each of these types of emergency situations can result from any number of causes and involve a variety of hazards or conditions.

FLOODING

Scenario 1:

Event: An unexpected wave washes over the decks of the submersible while a hatch is open.

Cause: Operating in high sea state (above 3) or a large wave is created by a passing ship.

Result: Water enters submersible causing it to sink if corrective action is not taken.

Scenario 2:

Event: Hatch cover or other hull penetration is left open during dive.

Cause: Equipment malfunction (hatch cover failure, etc.) or human error.

Result: Water enters submersible causing it to sink unless hatch cover or other hull penetration is not closed.

Scenario 3:

Event: Hatch cover, viewport, or other penetration fails or malfunctions.

Cause: Worn gasket, crack in viewport, fatigue, improper seating of hatch cover, seal, etc., impact, electrical overload causing burnthrough of seal.

Result: Water enters submersible causing it to sink if leakage is not controlled.

Scenario 4:

Event: Hull crack or failure occurs.

Cause: Collision, faulty weld, design fault, incorrect material, fabrication error, exceeding of rated depth, excessive corrosion, fatigue (excessive number of pressure cycles), or failure.

Result: Water enters submersible causing it to sink if leakage is not controlled. Hull crack leakage could possibly be controlled. Hull failure would most probably result in loss of the submersible.

Scenario 5:

Event: Submersible hits abandoned explosive.

Cause: Operating in area and unaware of presence of abandoned explosive.

Result: Explosion causes damage to hull and flooding.

SUBMERSIBLE IS UNABLE TO ASCEND OR DESCEND

Unable to ascend

Scenario 1:

Event: Submersible exceeds operating depth and is unable to ascend.

Cause: Increase in current speed, lack of knowledge concerning area depth, depth gauge failure, sliding down slope, sudden increase in depth, change in salinity of water, loss of air (for buoyancy).

Result: Submersible systems fail due to overpressure - submersible is unable to ascend resulting in air contamination after life support system consumables are exhausted. Hyperthermia or hypothermia (depending on water temperature), as a function of time.

Scenario 2:

Event: Submersible loses capability to surface.

Cause: Loss of air ballast, change in salinity of water, change in water temperature.

Result: Air contamination, hyperthermia or hypothermia occurs, as a function of time.

Scenario 3:

Event: Submersible settles on and becomes stuck on sea bed bottom, cannot extricate itself, and is unable to ascend.

Cause: Loss of power/buoyancy, lack of knowledge of sea bed bottom.

Result: Air contamination occurs; hyperthermia or hypothermia occurs, (depending on water temp) as a function of time.

Scenario 4:

Event: Falling of rock, mud slide onto vessel (damage or weight) prevents vessel from ascending.

Cause: Vibration from submersible or other vessel, submersible touches (hits) canyon wall causing an undersea avalanche.

Result: Air contamination occurs; hyperthermia or hypothermia occurs (depending on water temp.) both as a function of time.

Scenario 5:

Event: The submersible becomes entangled within rigging or cable of a wreck, other cable or within kelp and cannot ascend.

Cause: Vessel operates too close to the wreck, rigging,cable, etc.

Result: Air contamination occurs, hyperthermia or hypothermia occurs (depending on water temp.) both as a function of time.

Scenario 6:

Event: The submersible has a remote video camera which can be extended away from the vessel on a "tether." This tether becomes entangled around a rocky / coral outcropping and the vehicle is unable to ascend.

Cause: The tether is of long length and is not easily maneuverable.

Result: Air contamination, hypothermia or hyperthermia occurs (depending on water temp.)as a function of time.

Unable to Descend

Scenario :

Event: Inability to change positive buoyancy to negative.

Cause: Lack of power, control malfunction, air vents stuck in closed position.

Result: Collision with surface vessel, excessive pitch/roll ,or damage by high seas.

FIRE

Scenario 1:

Event: Battery explosion occurs.

Cause: Buildup of hydrogen gas and spark.

Result: Explosion/burning gas results in fire, burns, and /or air contamination.

Scenario 2:

Event: Electrical fire occurs.

Cause: Short circuit, faulty wiring, overloaded circuit, etc.

Result: Fire, loss of power, air contamination.

Scenario 3:

Event: Passenger strikes lighter or match for cigarette.

Cause: Lack of knowledge by passenger about "no smoking."

Result: Air contamination.

Scenario 4:

Event: Ignition of seats, floor occurs.

Cause: Passenger inadvertently ignites seats, bulkhead, overhead ceiling or deck.

Result: Submersible fire, air contamination, heat buildup, damage to equipment.

COLLISION

Scenario 1:

Event: Submersible collides with surface ship (support or other) while ascending.

Cause: Surface ship is unaware of submarine presence (lack of communication, failure to follow proper procedures, poor visibility, support ship is not on scene, failure of submersible steering, etc.).

Result: Damage to one or both vessels, flooding (see also Flooding), injury from impact, sinking, inability to surface).

Scenario 2:

Event: Submersible collides with another submersible while underwater.

Cause: Poor visibility, speed, current drift, loss of steering control, human error.

Result: Damage to vessel, flooding, injury from impact, sinking, inability to surface.

Scenario 3:

Event: Submersible collides with rocky or coral outcropping, or is attacked by large fish.

Cause: Poor visibility, speed, current drift, loss of steering control, human error, fish attack.

Result: Damage to vessel (flooding), injury from impact, sinking, inability to surface.

SUBMERSIBLE IS ISOLATED FROM SURFACE SUPPORT VESSEL

Scenario 1:

Event: Submersible loses contact with surface vessel at night, in fog or rain, or other weather conditions.

Cause: Loss of communication, drifting in current, loss of visibility.

Result: Mass passenger anxiety and/or seasickness, possible collision with other ships.

Scenario 2:

Event: Submersible loses contact with surface support vessel.

Cause: Radio or underwater telephone malfunction - redundant system also fails.

Result: Possible collision/inability to rendezvous with surface support.

AIR CONTAMINATION

Scenario 1:

Event: Battery gas, hydraulic fluid leakage or other toxic gas release occurs (see also Fire).

Cause: Lack of ventilation, malfunction of ventilation system, etc.

Result: Injury and possible death to passengers and crew.

Scenario 2:

Event: Insufficient supply of oxygen or buildup of CO_2.

Cause: Malfunction of oxygen supply or CO_2 scrubber system.

Result: Injury and possible death to passengers and crew.

Scenario 3:

Event: Oxygen buildup in hull.

Cause: Malfunction of oxygen supply system (leakage).

Result: Significant fire hazard and possible O_2 poisoning of passengers and crew.

PASSENGER INJURY /ILLNESS

Scenario 1:

Event: An unexpected wave washes over the deck of the submersible and passenger or crew is swept overboard.

Cause: Operating in high sea state (above 3) or sudden change in sea state due to wind or unexpected roll due to passing ship wake.

Result: Possible injury or drowning.

Scenario 2:

Event: Passenger slips or trips during transfer between submersible and taxi vessel.

Cause: Deck is slippery or uneven, no gangway and/ no railing used, crew does not assist.

Result: Possible fall or drowning especially if person is unable to swim. Physical crushing, if fall is between submersible and surface ship.

Scenario 3:

Event: Passenger becomes ill while inside submersible.

Cause: Air contamination, sensitive to pressure change, claustrophobia.

Result: Injury to self or others if not immediately treated.

SCENARIO REFERENCES

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4. Correspondence between Coast Guard and submersible companies.

APPENDIX B. GENERIC HAZARD CHECKLIST *

1. BASIC DESIGN DEFICIENCIES

a. Examples:

(1) Sharp corners
(2) Instability
(3) Excessive weight
(4) Inadequate clearance
(5) Lack of accessibility

b. Causes: Improper or poor design

c. Control Methods: Improve or change design

2. INHERENT HAZARDS

a. Examples:

(1) Mechanical (i.e., rotating equipment, vibration)
(2) Electrical
(3) Explosives
(4) Flammable gases or liquids
(5) Toxic substances
(6) Acceleration (flying objects)
(7) Deceleration (falling objects)
(8) Temperature

b. Cause: Integral characteristic which cannot be designed out

c. Control Methods:

(1) Safety Devices

(a) Isolation (separation)
(b) Barriers (guards)
(c) Interlocks (deactivation)
(d) Pressure release
(e) Temperature sensor (fuse)

(2) Warning Devices (Five Senses)

(a) Visual (eye) - color, shape, signs, light
(b) Auditory (hear) - bell
(c) Tactile (touch) - shape, texture
(d) Olfactory (smell)
(e) Gustatory (taste)

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*This checklist was developed by TSC using material adapted from Product Safety Management and Engineering by Willie Hammer, 1980.

(3) Procedures and Training

(a) Use of safe procedures
(b) Training
(c) Backout/recovery procedures
(d) Protective equipment
(e) Emergency procedures

3. MALFUNCTIONS

a. Examples:

(1) Structural failures
(2) Mechanical malfunctions
(3) Power failures
(4) Electrical malfunctions

b. Causes:

(1) Faulty design
(2) Manufacturing defects
(3) Improper or lack of maintenance
(4) Exceeding specified limits
(5) Environmental effects

c. Control Methods: Design

(1) Fail safe design
(2) Higher safety margins (i.e., reduce stress, increase load strength, etc.)
(3) Redundant circuitry or equipment
(4) Timed replacement

d. Other Control Methods: Safety devices, Warning Devices, Procedures and Training (See Point 2. c. 1-3)

4. MAINTENANCE HAZARDS

a. Examples:

(1) Improper connections
(2) Component failures
(3) Equipment damage
(4) Operational delay

b. Causes:

(1) Lack of maintenance
(2) Improper maintenance
(3) Hazardous maintenance conditions

c. Control Methods:

(1) Design

(a) Simplified design
(b) Fail-safe design
(c) Easy access to equipment
(d) Elimination of need for special tools or equipment

(2) Safety devices

(a) Guards for moving parts
(b) Interlocks

(3) Warning devices

(a) Labels/Signs
(b) Bells
(c) Chimes
(d) Lights

(4) Procedures or Training

(a) Documentation of proper procedures
(b) Improved training courses
(c) Housekeeping

5. ENVIRONMENTAL HAZARDS

a. Examples

(1) Heat
(2) Cold
(3) Dryness
(4) Wetness
(5) Low friction (slipperiness)
(6) Glare
(7) Darkness
(8) Earthquake
(9) Gas or other toxic fumes

b. Causes

(1) Inherent
(2) Foreseen or unforeseen natural phenomena/conditions which do or could occur

c. Control Methods (see also 4.c)

(1) Design

(a) Increased resistance to temperature changes
(b) Increased resistance to dryness or wetness
(c) Fail-safe design

(2) Safety Devices

(a) Sufficient heating or cooling capability
(b) Adequate insulation
(c) Restricted access
(d) Temperature sensor

(3) Warning devices

(a) Visual
(b) Auditory
(c) Smell

(4) Procedures and Training

(a) Use of safe procedures
(b) Protective equipment
(c) Training

6. HUMAN FACTORS

a. Examples: (Also see all other items)

(1) Stress (sensory, mental, motor)
(2) Physical surroundings (environment)

(a) Noise
(b) Illumination
(c) Temperature
(d) Energy sources
(e) Air and humidity
(f) Vibration

(3) Errors

(a) Omission
(b) Commission

(4) Nonrecognition of hazards
(5) Incorrect decisions
(6) Tasks done at wrong time
(7) Tasks not performed or incorrectly performed

b. Causes:

(1) Inadequate attention to human design criteria
(2) Poor location, layout of controls
(3) Equipment complexity
(4) Inherent hazards
(5) Incorrect installation
(6) Failure of warning devices
(7) Inadequacy of procedural safeguards

(a) Failure to follow instructions
(b) Lack of knowledge of procedures

(8) Inadequate training
(9) Lack of or improper maintenance

c. Control Methods:

(1) Design (to address items (1) - (6)
(2) Safety Devices (Redundancy)

(a) Isolation (separation)
(b) Barriers (guards)
(c) Interlocks (deactivation)
(d) Temperature sensor (fuse)

(3) Warning Devices (Five Senses) (Redundancy)

(a) Visual (eye) - color, shape, signs, light
(b) Auditory (hear) - bell
(c) Tactile (touch) - shape, texture
(d) Olfactory (smell)
(e) Gustatory (taste)

(4) Procedures and Training

(a) Clear warning labels (nature of hazard, action to avoid injury, consequences)
(b) Use of complete, proper, safe procedures
(c) Adequate training (also refresher training)
(d) Backout/recovery procedures
(e) Protective equipment
(f) Emergency procedures
(g) Proper maintenance procedures

APPENDIX C. PRELIMINARY HAZARD ANALYSIS

The Preliminary Hazard Analysis (PHA) presented in this appendix identifies potential hazards associated with the operation of passenger carrying submersibles. This PHA is based on the passenger carrying submersible system hazards described in the previously prepared system definition. The PHA format allows for the concise, systematic documentation of a great number of potential identified hazards. In fact, the PHA approach encouraged a broad, brainstorming thought process to consider as many hazards as possible.

The contents of the PHA worksheets are organized as follows. The control number for each line item is contained in the first column. This number identifies the line item and is derived from the combination of numbers which are assigned to each of the systems, subsystems, and hazard descriptions. Where there is more than one casual factor for a specific hazard description, each of the causal factors is assigned a letter. For example, the control number 1.1.01A results from combining the following numbers: 1 the Hull system, .1 for the Pressure hull subsystem, and .01 for the hazard description, Implosion/Collapse. The A indicates that the first cause (of five, in this case) of the hazard is Improper Design. The second column of the PHA worksheet contains a brief description of each hazard while the potential causes are noted in the third column. The fourth column describes the effect of the specific hazard. The fifth column contains the risk assessment category (RAC) and the hazard risk index (HRI) values assigned to each hazard description. (Refer to Figure 2-4). The RAC represents the hazard risk in terms of both the severity and probability (e.g., iD indicates the hazard is "Catastro," and "Remote"). The RACs are grouped into four numerical HRI categories. The HRI value (e.g., 1 = Unacceptable) is used to determine what management action is necessary. The RAC and HRI values are subjective and open to other opinion since adequate data is unavailable to actually determine the probability of the hazards.

The recommendations presented in column six of the PHA worksheets describe the method selected to eliminate the causes or minimize the effects of each hazard. In order of preference, the types of recommendations included are:

1. Design to eliminate or control hazards,
2. Provide safety devices,
3. Provide warning devices, and
4. Implement special procedures and training.

One or more recommendations are provided for each hazard cause identified. Many recommendations are based on existing codes, standards, and guidelines. However, a number of recommendations are either based on information which may need updating or are not currently addressed at all by existing references. At times, reference sources recommend different criteria (i.e., percent of CO_2 permitted); in such cases, all criteria are presented. In cases where no reference was located, the term TBD (To be Determined) was used.

The effect of the recommendation in terms of reducing the RAC and HRI is presented in column sever. (Note: This second RAC and HRI reflects a reduction in probability but not severity.)

The applicable sections of codes, standards and/or guidelines which were used as reference sources for the recommendations are identified in column eight. The references used are:

33 CFR	Code of Federal Regulations, Navigation and Navigable Waters, Volume 33, Parts 1 to 199, as applicable. Revised as of July 1, 1987.
46 CFR	Code of Federal Regulations, Shipping, Volume 46, Parts 1-199 Revised as of October 1, 1987.
ABS	American Bureau of Shipping, Underwater Systems and Vehicles Rules for Building and Classing, 1979.
ASME/ ANSI PVHO-1a	American Society of Mechanical Engineers and American National Standards Institute, Safety Standard for Pressure Vessels for Human Occupancy, July 1987.
NAVMAT P-9290	Naval Material Command, Naval Sea Systems Command, Naval Facilities Engineering Command, Systems Certification Procedures and Criteria Manual for Deep Submergence Systems. U.S. Navy, June 1976.
OPNAVINST P-9290.3	Certification of Operators of Manned Non-Combatant Submersibles, U.S. Navy. December 12, 1968.
MTSI	Marine Technology Society, Safety and Operational Guidelines for Undersea Vehicles, Book 1, Edited by John A. Pritzlaff, 1968.
MTSII	Marine Technology Society, Safety and Operational Guidelines for Undersea Vehicles, Book II, Edited by John A. Pritzlaff, 1974.
MTSIII	Marine Technology Society and Society for Underwater Technology, International Safety Standard Guidelines for Operation of Undersea Vehicles. Edited by John Pritzlaff, 1979.

DSPA	Deep Sea Pilots Association, Selection, Training and Qualification of Deep Submersible Pilots, 1971.
USCG May 1987	U.S. Coast Guard, Passenger Carrying Submersibles, May 19, 1987.
USCG Stability Guidelines	U.S. Coast Guard, Guidelines for Stability of Submersibles, July 1, 1988.

The ninth column, "Notes," was used to indicate whether hazards were considered time dependent.

SPECIAL NOTE: The Manning, Certification, and Licensing Requirements formerly contained in 46 CFR Subchapter B (Subparts 10 and 12) and Subchapter P (Subpart 157) were consolidated into Subchapter B as of January 8, 1989.

ELEMENT: SUBMERSIBLE
SYSTEM: HULL
SUBSYSTEM: PRESSURE HULL

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
1.1.01A	IMPLOSION OR FAILURE OF PRESSURE HULL	IMPROPER DESIGN OF PRESSURE HULL	FLOODING	ID	1	FOLLOW CFR, MTS, ASME, ABS AND NAVY FOR DESIGN OF PRESSURE HULL. USCG PLAN REVIEW.	IE	3	46 CFR 54, 197.328. MTS II, SECTION B.2.0 & B.4.0. ASME PVHO-1A, SECTION 1.3. ABS, SECTION 9. NAVMAT P-9290, APPENDIX B. USCG, MAY 87, P. 3.	
1.1.01B	IMPLOSION OR FAILURE OF PRESSURE HULL	IMPROPER MATERIAL SELECTION FOR PRESSURE HULL	FLOODING	IC	1	FOLLOW CFR, ASME, ABS, AND NAVY FOR PRESSURE BOUNDARY MATERIAL SPECIFICATIONS AND TESTING.	IE	3	46 CFR 176.05, 176.10, 177.10-1. ASME PVHO-1A, SECTION 1.2. ABS, SECTION 3. NAVMAT P-9290, APPENDIX A.	
1.1.01C	IMPLOSION OR FAILURE OF PRESSURE HULL	IMPROPER FABRICATION OF PRESSURE HULL	FLOODING	IC	1	FOLLOW CFR, ASME, ABS, AND NAVY FOR FABRICATION. INSPECTION DURING MANUFACTURING.	IE	3	46 CFR 177.10-1. ASME PVHO-1A, SECTION 1.3. ABS, SECTION 4. NAVMAT P-9290, CHAPTER 4 & SECTION B.3. INSPECTION: 46 CFR 176.05, 176.10, ABS, SECTION C.17.	

ELEMENT: SUBMERSIBLE
SYSTEM: HULL
SUBSYSTEM: PRESSURE HULL

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
1.1.01D	IMPLOSION OR FAILURE OF PRESSURE HULL	VESSEL DESCENDS BELOW CERTIFIED DEPTH (SEE ALSO 2.2, 6.1, 8.2, AND 8.3)	FLOODING	IC	1	DEPTH INDICATOR/ ALARM. USCG PLAN REVIEW. RESTRICTED OPERATING AREA.	IE	3	INSTRUMENTATION: MTS III, SECTION C.1.3, 46 CFR 54.10. USCG, MAY 87, P.6. OPERATING AREA: TBD.	TIME/DEPTH DEPENDENT.
1.1.01E	IMPLOSION OR FAILURE OF PRESSURE HULL	IMPROPER OR LACK OF MAINTENANCE TO PRESSURE HULL (SEE ALSO 6.4)	FLOODING	IC	1	FOLLOW CFR FOR PERIODIC TESTS & INSPECTIONS OF VESSEL. FOLLOW ABS AND MTS FOR PREVENTIVE MAINTENANCE. TRAINING PROGRAM.	IE	3	TESTS: 46 CFR 54.10, 176.05, 176.10, 197.462. MAINTENANCE: ABS, SECTION B.45, MTS I, SECTION H, MTS II, SECTION J. TRAINING: MTS I, SECTION I.	TIME DEPENDENT.
1.1.02A	LEAKAGE THROUGH PRESSURE HULL	CORROSION CREATES HOLES THROUGH PRESSURE HULL	FLOODING	IIC	2	FOLLOW CFR, ABS, AND ASME FOR DESIGN FOR PROTECTION AGAINST CORROSION. PREVENTIVE MAINTENANCE PROGRAM.	IID	2	46 CFR 54.01, 54.25. ABS, SECTION 3.7. ASME PVHO-1A, SECTION 1.2.3. MAINTENANCE: ABS, SECTION B.45, MTS I, SECTION H, MTS II, SECTION J.	TIME DEPENDENT.
1.1.02B	LEAKAGE THROUGH PRESSURE HULL	COLLISION OR ACCIDENT DAMAGES PRESSURE HULL	FLOODING	IIC	1	PROVIDE PROPER EMERGENCY PROCEDURES.	IID	2	MTS III, SECTION B.4.6.2. USCG, MAY 87, P.6.	TIME DEPENDENT.

ELEMENT: SUBMERSIBLE
SYSTEM: HULL
SUBSYSTEM: PRESSURE HULL

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
1.1.02C	LEAKAGE THROUGH PRESSURE HULL	EXCEEDING ALLOWABLE NUMBER OF PRESSURE CYCLES	FLOODING	IIC	2	SUBMIT A FATIGUE ANALYSIS PER ABS AND NAVY REQUIREMENTS. LIMIT THE NUMBER OF DIVES.	IID	2	ABS, SECTION 9.9. NAVMAT P-9290, SECTION B.2. DIVE LIMIT: TBD.	TIME DEPENDENT

ELEMENT: SUBMERSIBLE
SYSTEM: HULL
SUBSYSTEM: HULL PENETRATIONS

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
1.2.01A	LEAKAGE AROUND HATCH	IMPROPER DESIGN OR MATERIAL SELECTION FOR HATCH INSERT OR HATCH COVER	FLOODING	IID	2	FOLLOW NAVY, AND ABS FOR DESIGN OF HATCH AND FOR PRESSURE BOUNDARY MATERIAL SELECTION. USCG PLAN REVIEW.	IIE	3	NAVMAT P-9290, SECTION B.2.5.C. ABS SECTION 3. USCG, MAY 87, P.3.	TIME DEPENDENT.
1.2.01B	LEAKAGE AROUND HATCH	IMPROPER FABRICATION OR INSTALLATION OF HATCH OR HATCH COVER	FLOODING	IIC	2	FOLLOW ABS FOR FABRICATION. INSPECTION DURING MANUFACTURE.	IIE	3	ABS, SECTION 4. INSPECTION: 46 CFR 176.05, 176.10, ABS, SECTION C.17.	TIME DEPENDENT.
1.2.01C	LEAKAGE AROUND HATCH	IMPROPER OR LACK OF MAINTENANCE FOR HATCH COVER (SEE ALSO 6.4)	FLOODING	IIC	2	PREVENTIVE MAINTENANCE PROGRAM. TRAINING PROGRAM.	IIE	3	MAINTENANCE: ABS, SECTION B.45, MTS I, SECTION H. MTS II, SECTION J. TRAINING: MTS I, SECTION I.	TIME DEPENDENT.
1.2.01D	LEAKAGE AROUND HATCH	HATCH COVER NOT PROPERLY SEATED	FLOODING	IIB	1	FOLLOW CFR TO ENSURE PROPER SECURING OF HATCHES. PROVIDE PROPER OPERATING PROCEDURES FOR SECURING HATCH.	IIC	2	46 CFR 185.20-15. OP PROC: MTS III, SECTION B.2.	TIME DEPENDENT.
1.2.01E	FLOODING INTO HATCH	HATCH COVER NOT CLOSED PRIOR TO SUBMERGING (SEE ALSO 6.1)	FLOODING	IC	1	FOLLOW CFR TO ENSURE PROPER SECURING OF HATCHES. HATCH CLOSED INDICATOR OR LOCKOUT SWITCH.	IE	3	46 CFR 185.20-15. CLOSED INDICATOR/ SWITCH: TBD.	TIME DEPENDENT.

ELEMENT: SUBMERSIBLE
SYSTEM: HULL
SUBSYSTEM: HULL PENETRATIONS

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
1.2.02A	LEAKAGE THROUGH OR AROUND VIEWPORT PENETRATION	IMPROPER DESIGN OR MATERIAL SELECTION FOR VIEWPORT, VIEWPORT INSERT, OR VIEWPORT PENETRATION	FLOODING	IID	2	FOLLOW ABS, ASME, AND NAVY FOR DESIGN AND MATERIAL SELECTION FOR VIEWPORTS. USCG PLAN REVIEW.	IIE	3	ABS SECTION 8. ASME PVHO-1A, SECTION 2 AND APPENDIX A. NAVMAT P-9290, SECTION B.2.5.B. USCG, MAY 87, P.2.	TIME DEPENDENT.
1.2.02B	LEAKAGE THROUGH OR AROUND VIEWPORT PENETRATION	IMPROPER FABRICATION OR INSTALLATION OF VIEWPORT, VIEWPORT INSERT, OR VIEWPORT PENETRATION	FLOODING	IIC	2	FOLLOW ABS AND ASME FOR FABRICATION, AND TESTING OF VIEWPORTS. INSPECTION DURING MANUFACTURE.	IIE	3	ABS SECTION 9. ASME PVHO-1A, SECTION 2 AND APPENDIX A. INSPECTION: 46 CFR 176.05, 176.10, ABS, SECTION C.17..	TIME DEPENDENT.
1.2.02C	LEAKAGE THROUGH OR AROUND VIEWPORT PENETRATION	IMPROPER OR LACK OF MAINTENANCE TO VIEWPORT, VIEWPORT INSERT, OR VIEWPORT PENETRATION (SEE ALSO 6.4)	FLOODING	IIC	2	PREVENTIVE MAINTENANCE PROGRAM TO INSPECT VIEWPORT GASKETS SEAL AND VIEWPORT PANE MATERIAL REGULARLY. FOLLOW ASME DESIGN LIFE STANDARDS.	IIE	3	MAINTENANCE: ABS, SECTION B.45. MTS I, SECTION H. MTS II, SECTION J. ASME PVHO-1A, SEC 2.14	TIME DEPENDENT.

ELEMENT: SUBMERSIBLE
SYSTEM: HULL
SUBSYSTEM: HULL PENETRATIONS

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
1.2.02D	LEAKAGE THROUGH OR AROUND VIEWPORT PENETRATION	DAMAGE TO VIEWPORT FROM INSIDE SUB	FLOODING	IIC	2	PROVIDE SHIELDING OF VIEWPORT FROM DAMAGE. ESTABLISH OPERATING PROCEDURE TO WARN PASSENGERS OF NECESSARY SAFETY MEASURES.	IIE	3	NAVMAT P-9290, SECTION B.2.5.B. USCG, MAY 87, P.2.	TIME DEPENDENT
1.2.02E	FLOODING THROUGH DAMAGED VIEWPORT/ VIEWPORT PENETRATION.	DAMAGE TO VIEWPORT FROM INSIDE SUB	FLOODING	IC	1	PROVIDE SHIELDING OF VIEWPORT FROM DAMAGE. ESTABLISH OPERATING PROCEDURE TO WARN PASSENGERS OF NECESSARY SAFETY MEASURES.	IE	3	SHIELDING: TBD. OP PROC: MTS III, SECTION B.2.	
1.2.02F	LEAKAGE THROUGH OR AROUND VIEWPORT PENETRATION	DAMAGE TO VIEWPORT FROM OUTSIDE SUB	FLOODING	IIC	2	PROVIDE EXTERNAL GUARDS TO VIEWPORT TO PROTECT FROM DAMAGE. PROVIDE PROPER OPERATING PROCEDURES.	IIE	3	NAVMAT, P-9290, SECTION B.2.5.B. USCG, MAY 87, P.2. OP PROC: MTS III, SECTION B.2.	TIME DEPENDENT
1.2.02G	FLOODING THROUGH VIEWPORT	DAMAGE TO VIEWPORT FROM OUTSIDE SUB	FLOODING	IC	1	PROVIDE EXTERNAL GUARDS TO VIEWPORT TO PROTECT FROM DAMAGE. PROVIDE PROPER OPERATING PROCEDURES.	IE	3	GUARDS: NAVMAT P-9290, SECTION B.2.5.B. OP PROC: MTS III, SECTION B.2.	

ELEMENT: SUBMERSIBLE
SYSTEM: HULL
SUBSYSTEM: HULL PENETRATIONS

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
1.2.03A	LEAKAGE THROUGH ELECTRICAL PENETRATION	IMPROPER DESIGN OR MATERIAL SELECTION FOR ELECTRICAL PENETRATIONS	FLOODING	IIC	2	GENERAL ARRANGEMENT, CYCLIC TESTS, PENETRATION DESIGN, MATERIAL SELECTION, AND PENETRATION REINFORCEMENT PER CFR, ABS, ASME AND NAVY. SUBDIVIDE TO ISOLATE PENETRATIONS. USCG PLAN REVIEW.	IIE	3	GEN ARRGMT, CYCL TEST: ABS, 7.17. PENTRTN REINFORCE: ABS, 9.7, ASME PVHO-1A, 1.3.4. MATL SELCTN: ABS, 3, ASME PVHO-1A, 1.2. PENTRTN DESIGN: 46 CFR 159, NAVMAT, B.2.5A. USCG, MAY 87, P.1, 3.	TIME DEPENDENT
1.2.03B	LEAKAGE THROUGH ELECTRICAL PENETRATION	IMPROPER FABRICATION OR INSTALLATION OF ELECTRICAL PENETRATIONS	FLOODING	IIC	2	PENETRATION TEST PER ABS. FABRICATION PER ABS AND ASME. SUBMERGED ELECTRIC CABLES TESTS PER ABS. INSPECTION DURING FABRICATION.	IIE	3	PENETRATION TEST: ABS, SECTION 7.17. FABRICATION: ABS, SECTION 4, ASME PVHO-1A, 1.3. CABLE TESTS: ABS, SECTION 7.19.1. INSPECTION: 46 CFR 176.05, 176.10. ABS, SECTION C.17.	TIME DEPENDENT
1.2.03C	LEAKAGE THROUGH ELECTRICAL PENETRATION	IMPROPER OR LACK OF MAINTENANCE TO ELECTRICAL PENETRATIONS (SEE ALSO 6.4)	FLOODING	IIC	2	PREVENTIVE MAINTENANCE PROGRAM. TRAINING PROGRAM.	IIE	3	MAINTENANCE: ABS, SECTION B.45. MTS I, SECTION H, MTS II, SECTION J. TRAINING: MTS I, SECTION I.	TIME DEPENDENT

ELEMENT: SUBMERSIBLE
SYSTEM: HULL
SUBSYSTEM: HULL PENETRATIONS

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
1.2.03D	LEAKAGE THROUGH ELECTRICAL PENETRATION	DAMAGE TO PENETRATION FROM OUTSIDE SUB	FLOODING	IIC	2	SUBMERGED ELECTRIC CABLES TESTS AND PROTECTION FROM DAMAGE DURING HANDLING AS PER ABS.	IID	2	HANDLING DAMAGE PROTECTION: ABS, SECTION 2.15.	TIME DEPENDENT.
1.2.03E	LEAKAGE THROUGH ELECTRICAL PENETRATION	FIRE DAMAGE TO ELECTRICAL PENETRATION DUE TO SHORT CIRCUIT	FLOODING	IIC	2	PROVIDE POWER LEADS WITH FAULT CIRCUIT AND OVERLOAD PROTECTION DEVICES PER ABS.	IID	2	ABS, SECTION 7.11.2	TIME DEPENDENT.
1.2.04A	LEAKAGE THROUGH MECHANICAL PENETRATION	IMPROPER DESIGN OR MATERIAL SELECTION FOR MECHANICAL PENETRATIONS	FLOODING	IID	2	REINFORCE PENETRATION AND MATERIAL SELECTION PER ABS, AND ASME. USCG PLAN REVIEW.	IIE	3	PENETRATION REINFORCEMENT: ABS, SECTION 9.7, ASME PVHO-1A, 1.3.4. MATERIAL SELECTION: ABS, SECTION 3, ASME PVHO-1A, 1.2. USCG, MAY 87, P.3.	TIME DEPENDENT.
1.2.04B	LEAKAGE THROUGH MECHANICAL PENETRATION	IMPROPER FABRICATION OR INSTALLATION OF MECHANICAL PENETRATIONS	FLOODING	IIC	2	FOLLOW ABS FOR PRESSURE TEST STANDARDS. FABRICATION PER ABS AND ASME. INSPECTION DURING MANUFACTURE.	IIE	3	ABS, SECTION 4, ASME PVHO, 1.3. INSPECTION: 46 CFR 176.05, 176.10, ABS, SECTION C.17.	TIME DEPENDENT.

ELEMENT: SUBMERSIBLE
SYSTEM: HULL
SUBSYSTEM: HULL PENETRATIONS

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
1.2.04C	LEAKAGE THROUGH MECHANICAL PENETRATION	IMPROPER OR LACK OF MAINTENANCE TO MECHANICAL PENETRATIONS (SEE ALSO 6.4)	FLOODING	IIC	2	PREVENTIVE MAINTENANCE PROGRAM. TRAINING PROGRAM.	IIE	3	MAINTENANCE: ABS, SECTION B.45, MTS I, SECTION H, MTS II, SECTION J. TRAINING: MTS I, SECTION I.	
1.2.04D	LEAKAGE THROUGH MECHANICAL PENETRATION	DAMAGE TO MECHANICAL PENETRATION FROM OUTSIDE SUB	FLOODING	IIC	2	PROVIDE PROTECTION/ LOCATION FROM DAMAGE DURING HANDLING PER ABS.	IID	2	ABS, SECTION 2.15	TIME DEPENDENT.
1.2.05A	LEAKAGE THROUGH PIPING PENETRATION	IMPROPER DESIGN OR MATERIAL SELECTION FOR PIPING PENETRATIONS	FLOODING	IIC	2	DESIGN PIPING WITH ASSOCIATED VALVES AND FITTINGS PER ABS. REINFORCE PENETRATION PER ABS & ASME. MATERIAL SELECTION PER ABS & ASME. SUBDIVIDE TO ISOLATE PENETRATIONS. USCG PLAN REVIEW.	IIE	3	PIPING DESIGN: ABS, SECTION 6.5.2. PENTRTN REINFORCE: ABS, SECTION 9.7, ASME PVHO-1A, 1.3.4. MATL SELCTN: ABS, SECTION 3, ASME PVHO-1A, 1.2. USCG, MAY 87, P.1, 3.	TIME DEPENDENT.
1.2.05B	LEAKAGE THROUGH PIPING PENETRATION	IMPROPER FABRICATION OR INSTALLATION OF PIPING PENETRATIONS	FLOODING	IIC	2	FABRICATION PER ABS AND ASME. INSPECTION DURING MANUFACTURE.	IIE	3	ABS, SECTION 4, ASME PVHO-1A, 1.3. INSPECTION: 46 CFR 176.05, 176.10, ABS, SECTION C.17.	TIME DEPENDENT.

ELEMENT: SUBMERSIBLE
SYSTEM: HULL
SUBSYSTEM: HULL PENETRATIONS

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
1.2.05C	LEAKAGE THROUGH PIPING PENETRATION	IMPROPER OR LACK OF MAINTENANCE TO PIPING PENETRATIONS (SEE ALSO 6.4)	FLOODING	IIC	2	PREVENTIVE MAINTENANCE PROGRAM. TRAINING PROGRAM.	IIE	3	MAINTENANCE: ABS, SECTION B.45, MTS I, SECTION H, MTS II, SECTION J. TRAINING: MTS I, SECTION I.	TIME DEPENDENT
1.2.05D	LEAKAGE THROUGH PIPING PENETRATION	DAMAGE TO PIPING PENETRATION FROM OUTSIDE SUB	FLOODING	IIC	2	PROVIDE PROPER OPERATING PROCEDURES (SEE SECTION 6.1). DESIGN EXTERNAL PIPING, VALVES, AND FITTINGS PER ABS.	IID	2	EXTERNAL PIPING: ABS, SECTION 6.5.1, 6.5.3. VALVES AND FITTINGS: ABS, SECTION 6.5.2.	TIME DEPENDENT

ELEMENT: SUBMERSIBLE
SYSTEM: HULL
SUBSYSTEM: EXOSTRUCTURE AND ATTACHMENTS

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
1.3.01A	FAILURE OF PRESSURE VESSEL FOR AIR SYSTEM (SEE ALSO 3.1.01E)	IMPROPER DESIGN OR SELECTION OF AIR STORAGE CYLINDERS	INABILITY TO SURFACE	IID	2	FOLLOW CFR FOR USE OF HIGH PRESSURE AIR STORAGE CYLINDERS. USCG PLAN REVIEW.	IIE	3	46 CFR 54, CLASS I PRESSURE VESSELS, USCG, MAY 87, P.3.	TIME DEPENDENT
1.3.01B	FAILURE OF PRESSURE VESSEL FOR AIR SYSTEM (SEE ALSO 3.1.01E)	IMPROPER INSTALLATION OF AIR STORAGE CYLINDERS	INABILITY TO SURFACE	IID	2	PRESSURE VESSELS PER CFR. INSPECTION DURING MANUFACTURE.	IIE	2	46 CFR 54, 197.338. INSPECTION: 46 CFR 176.05, 176.10, ABS, SECTION C.17.	TIME DEPENDENT
1.3.01C	FAILURE OF PRESSURE VESSEL FOR A.R SYSTEM (SEE ALSO 3.1.01E)	COLLISION OR ACCIDENT DAMAGES AIR STORAGE CYLINDERS	INABILITY TO SURFACE	IID	2	PROVIDE PROTECTION/ LOCATION FROM DAMAGE DURING HANDLING PER ABS	IIE	3	ABS, SECTION 2.15	TIME DEPENDENT
1.3.02A	FAILURE OF PRESSURIZED TANK FOR TRIM SYSTEM (SEE ALSO 2.1.04I)	IMPROPER DESIGN OR MATERIAL SELECTION FOR TRIM TANKS	ROLLING, INJURY DUE TO FALL	IID	2	DESIGN PRESSURE VESSEL PER CFR, ABS, & ASME. MATERIAL SELECTION PER ABS. USCG PLAN REVIEW.	IIE	3	DESIGN: 46 CFR 54 CLASS II PRESSURE VESSELS, 46 CFR 159. ABS, SECTION 9, ASME PVHO-1A, 1.3. MATERIAL SELECTION: ABS, SECTION 3. USCG , MAY 87, P.3.	TIME DEPENDENT.

ELEMENT: SUBMERSIBLE
SYSTEM: HULL
SUBSYSTEM: EXOSTRUCTURE AND ATTACHMENTS

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
1.3.02B	FAILURE OF PRESSURIZED TANK FOR TRIM SYSTEM (SEE ALSO 2.1.041)	IMPROPER FABRICATION OR INSTALLATION OF TRIM TANKS	ROLLING, INJURY DUE TO FALL	IID	2	FABRICATION PER CFR, ABS, AND ASME. INSPECTION DURING MANUFACTURE.	IIE	3	46 CFR 54 CLASS II PRESSURE VESSELS. ABS, SECTION 4. ASME PVHO-1A, 1.3. INSPECTION: 46 CFR 176.05, 176.10, ABS, SECTION C.17.	TIME DEPENDENT.
1.3.02C	FAILURE OF PRESSURIZED TANK FOR TRIM SYSTEM (SEE ALSO 2.1.041)	COLLISION OR ACCIDENT DAMAGES TRIM TANK	ROLLING, INJURY DUE TO FALL	IIC	2	PROVIDE PROTECTION/ LOCATION FROM DAMAGE DURING HANDLING PER ABS.	IIE	3	ABS, SECTION 2.15	TIME DEPENDENT.
1.3.03A	FAILURE OF PRESSURE VESSEL FOR OXYGEN (SEE ALSO 3.6.011)	IMPROPER DESIGN OR MATERIAL SELECTION FOR PRESSURE VESSELS	AIR CONTAMINATION	IID	2	FOLLOW CFR FOR OXYGEN CYLINDERS. DOT APPROVED STOWAGE REQUIREMENTS QUANTITY < 1500 CU. FT. USCG PLAN REVIEW.	IIE	3	46 CFR 147.05-100. USCG, MAY 1987, P.3.	TIME DEPENDENT.
1.3.03B	FAILURE OF PRESSURE VESSEL FOR OXYGEN (SEE ALSO 3.6.011)	IMPROPER FABRICATION OR INSTALLATION OF PRESSURE VESSELS	AIR CONTAMINATION	IIC	2	DOT APPROVED STOWAGE REQUIREMENTS QUANTITY < 1500 CU. FT. INSPECTION DURING MANUFACTURE.	IIE	3	46 CFR 147.05-100, INSPECTION: 46 CFR 176.05, 176.10, ABS, SECTION C.17.	TIME DEPENDENT.
1.3.03C	FAILURE OF PRESSURE VESSEL FOR OXYGEN (SEE ALSO 3.6.011)	COLLISION OR ACCIDENT DAMAGES OXYGEN STORAGE CYLINDERS	AIR CONTAMINATION	IIC	2	PROVIDE PROTECTION/ LOCATION FROM DAMAGE DURING HANDLING PER ABS	IID	2	ABS, SECTION 2.15	TIME DEPENDENT.

ELEMENT: SUBMERSIBLE
SYSTEM: HULL
SUBSYSTEM: EXOSTRUCTURE AND ATTACHMENTS

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
1.3.04A	FAILURE OF PRESSURIZED OR	IMPROPER DESIGN OR MATERIAL SELECTION FOR PIPE OR HOSE	INABILITY TO SURFACE, FLOODING	IID	2	FOLLOW ABS, AND NAVY DESIGN REQUIREMENTS FOR EXTERNAL PIPING. USCG PLAN REVIEW.	IIE	3	ABS, SECTION 6.5. NAVMAT P-9290, SECTION B.2.3. USCG, MAY 87, P.3.	TIME DEPENDENT.
1.3.04B	FAILURE OF PRESSURIZED PIPE OR HOSE	IMPROPER FABRICATION OR INSTALLATION OF PIPE OR HOSE	INABILITY TO SURFACE, FLOODING	IIC	2	INSPECTION DURING MANUFACTURE.	IIE	3	46 CFR 176.05, 176.10, ABS, SECTION C.17.	TIME DEPENDENT.
1.3.04C	FAILURE OF PRESSURIZED PIPE OR HOSE	COLLISION OR ACCIDENT DAMAGES PIPE OR HOSE	INABILITY TO SURFACE, FLOODING	IIC	2	DESIGN VALVES & FITTINGS PER ABS. PROVIDE PROTECTION/ LOCATION FROM DAMAGE DURING HANDLING PER ABS. PROVIDE PROPER OPERATING PROCEDURES.	IIE	3	VALVE/FITTING DESIGN: ABS, SECTION 6.5.2. PROTECTION: ABS, SECTION 2.15. OP PROC: MTS III, SECTION B.2.	TIME DEPENDENT.
1.3.05	LEAKAGE INTO CABIN THROUGH DAMAGED EXTERNAL PIPING	COLLISION OR ACCIDENT DAMAGES EXTERNAL PIPING PENETRATING PRESSURE HULL	FLOODING	IIC	2	PROVIDE PROTECTION/ LOCATION FROM DAMAGE DURING HANDLING PER ABS. PROVIDE COMBINATION OR STOP AND CHECK VALVES.	IIE	3	ABS, SECTION 2.15, SECTION 6.5.2. VALVES: TBD.	TIME DEPENDENT.

ELEMENT: SUBMERSIBLE
SYSTEM: HULL
SUBSYSTEM: EXOSTRUCTURE AND ATTACHMENTS

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
1.3.06A	FAILURE OF LIFTING POINT ATTACHMENT WHILE RETRIEVING SUB FROM SEA BOTTOM OR SURFACE	IMPROPER DESIGN OR MATERIAL SELECTION FOR LIFTING POINT ATTACHMENT	INABILITY TO SURFACE, COLLISION	IIC	2	FOLLOW ABS AND ASME GUIDELINES FOR DESIGN TO WITHSTAND DYNAMIC FORCES UNDER WORST CASE SCENARIOS. ACCEPTANCE AND PERIODIC INSPECTION AND TESTING. USCG PLAN REVIEW.	IIE	3	ABS SECTION 2.9. ASME PVHO-1A, 1.3.5. INSPECTION: 46 CFR 176.05, 176.10, ABS, SECTION C.17. USCG, MAY 87, P.3.	TIME DEPENDENT.
1.3.06B	FAILURE OF LIFTING POINT ATTACHMENT WHILE RETRIEVING SUB FROM SEA BOTTOM OR SURFACE	IMPROPER FABRICATION OR INSTALLATION OF LIFTING POINT ATTACHMENT	INABILITY TO SURFACE, COLLISION	IIC	2	FOLLOW ABS AND ASME FOR FABRICATION. INSPECTION DURING MANUFACTURE.	IIE	3	ABS, SECTION 4. ASME PVHO-1A, 1.3.5. INSPECTION: 46 CFR 176.05, 176.10, ABS, SECTION C.17.	TIME DEPENDENT.
1.3.06C	FAILURE OF LIFTING POINT ATTACHMENT WHILE RETRIEVING SUB FROM SEA BOTTOM OR SURFACE	IMPROPER USE OF EMERGENCY LIFTING POINT.	INABILITY TO SURFACE, COLLISION	IIC	2	EMERGENCY PROCEDURES.	IID	2	MTS III, SECTION C.1.7.	TIME DEPENDENT.
1.3.06D	FAILURE OF LIFTING POINT ATTACHMENT WHILE RETRIEVING SUB FROM SEA BOTTOM OR SURFACE	IMPROPER OR LACK OF MAINTENANCE TO LIFTING POINT ATTACHMENTS (SEE ALSO 6.4)	INABILITY TO SURFACE, COLLISION	IIC	2	PREVENTIVE MAINTENANCE PROGRAM TO INSPECT AND TEST ATTACHMENT REGULARLY.	IIE	3	MAINTENANCE: ABS, SECTION B.45, MTS I, SECTION H, MTS II, SECTION J. TESTING: 46 CFR 176.	TIME DEPENDENT.

ELEMENT: SUBMERSIBLE
SYSTEM: HULL
SUBSYSTEM: EXOSTRUCTURE AND ATTACHMENTS

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
1.3.06E	INABILITY TO SAFELY LIFT SUBMERSIBLE FOR RETRIEVAL OPERATIONS	ONLY ONE LIFTING ATTACHMENT IS AVAILABLE TO LIFT SUBMERSIBLE	INABILITY TO SURFACE, INABILITY TO RESCUE, COLLISION	IID	2	REQUIRE SEVERAL REDUNDANT LIFT POINTS. EMERGENCY LIFT AND TOW POINTS SEPARATE FROM THOSE FOR ROUTINE HANDLING. PROVIDE PROPER EMERGENCY PROCEDURES.	IIE	3	LIFT POINTS: MTS III, SECTION C.1.7, NAVMAT P-9290, SECTION B.7.7. EMER PROC: MTS III, SECTION B.4.4A.	TIME DEPENDENT.
1.3.07A	FAILURE OF PRESSURIZED TANK FOR BALLAST SYSTEM (SEE ALSO 2.1.01K)	IMPROPER DESIGN OR MATERIAL SELECTION FOR BALLAST TANKS	INABILITY TO SURFACE	IID	2	DESIGN AND SELECT MATERIAL PER ABS, AND ASME. USCG PLAN REVIEW.	IIE	3	46 CFR 54, CLASS II PRESSURE VESSELS. DESIGN: ABS, SECTION 9. MATL SELCTN: ABS, SECTION 3, ASME PVHO-1A, 1.2. USCG, MAY 87, P.3.	TIME DEPENDENT.
1.3.07B	FAILURE OF PRESSURIZED TANK FOR BALLAST SYSTEM (SEE ALSO 2.1.01K)	IMPROPER FABRICATION OR INSTALLATION OF BALLAST TANKS	INABILITY TO SURFACE	IIC	2	FABRICATION PER CFR, ABS, AND ASME. INSPECTION DURING MANUFACTURE.	IIE	3	46 CFR 54, CLASS II PRESSURE VESSELS. ABS, SECTION 4. ASME PVHO-1A, 1.3. INSPECTION: 46 CFR 176.05, 176.10, ABS, SECITON C.17.	TIME DEPENDENT.
1.3.07C	FAILURE OF PRESSURIZED TANK FOR BALLAST SYSTEM (SEE ALSO 2.1.01K)	COLLISION OR ACCIDENT DAMAGES BALLAST TANKS	INABILITY TO SURFACE	IIC	2	PROVIDE PROTECTION/ LOCATION FROM DAMAGE DURING HANDLING PER ABS.	IIE	3	ABS, SECTION 2.15	TIME DEPENDENT.

ELEMENT: SUBMERSIBLE
SYSTEM: HULL
SUBSYSTEM: EXOSTRUCTURE AND ATTACHMENTS

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HR1	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HR12	HAZARD CONTROL REFERENCES	NOTES
1.3.08A	EXOSTRUCTURE OR ATTACHMENT BREAKS AWAY LEAVING HOLE IN PRESSURE HULL	IMPROPER DESIGN OR MATERIAL SELECTION FOR JOINTS	LEAKAGE/ FLOODING	IID	2	FOLLOW CFR AND ABS FOR DESIGN AND MATERIAL SELECTION FOR PRESSURE SPECIFICATIONS. USCG PLAN REVIEW.	IIE	3	46 CFR 159. ABS, SECTIONS 3, 6.9, & 9.17. USCG, MAY 87, P.3.	TIME DEPENDENT.
1.3.08B	EXOSTRUCTURE OR ATTACHMENT BREAKS AWAY LEAVING HOLE IN PRESSURE HULL	IMPROPER FABRICATION OF JOINTS	LEAKAGE/ FLOODING	IID	2	FOLLOW ABS FOR FOUNDATIONS FOR ATTACHMENTS TO PRESSURE BOUNDARIES. FABRICATION PER ABS. BREAKAWAY DESIGN. INSPECTION DURING MANUFACTURE.	IIE	3	ATTACHMENTS: ABS, SECTIONS 6.9 & 9.17. FABRICATION: ABS, SECTION 4. BREAKAWAY: TBD. INSPECTION: 46 CFR 176.05, 176.10, ABS, SECTION C.17.	TIME DEPENDENT.
1.3.08C	EXOSTRUCTURE OR ATTACHMENT BREAKS AWAY LEAVING HOLE IN PRESSURE HULL	CORROSION AT JOINT BETWEEN PRESSURE HULL AND ATTACHMENT	LEAKAGE/ FLOODING	IID	2	FOLLOW ABS AND ASME FOR MATERIAL SELECTION FOR CORROSION RESISTANCE. PREVENTIVE MAINTENANCE PROGRAM.	IIE	3	ABS, SECTION 3.7.2. ASME PVHO-1A, 1.3.5. MAINTENANCE: ABS, SECTION B.45, MTS I, SECTION H, MTS II, SECTION J.	TIME DEPENDENT

ELEMENT: SUBMERSIBLE
SYSTEM: SHIP CONTROL
SUBSYSTEM: BALLAST AND TRIM

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
2.1.01A	UNCONTROLLABLE DESCENT OR ASCENT	IMPROPER DESIGN, SIZING, OR MATERIAL SELECTION FOR BALLAST SYSTEM	INABILITY TO SURFACE OR TO STAY SUBMERGED	IID	2	FOLLOW CFR, ABS, ASME FOR THE DESIGN AND CONSTRUCTION OF CLASS II PRESSURE VESSELS. FOLLOW MTS FOR DESIGN OF BALLAST SYSTEM. USCG PLAN REVIEW.	IIE	3	46 CFR 54.01-5, CLASS II PRESSURE VESSELS. MTS I, SECTIONS E.4.2 AND A.2.2. ABS, SECTIONS 2.19, 3, & 9. ASME PVHO-1A, 1.2. USCG, MAY 87, P.3.	TIME DEPENDENT.
2.1.01B	UNCONTROLLABLE DESCENT OR ASCENT	IMPROPER FABRICATION OR INSTALLATION OF BALLAST SYSTEM	INABILITY TO SURFACE OR TO STAY SUBMERGED	IIC	2	FOLLOW CFR, ASME, AND ABS FOR FABRICATION OF PRESSURE VESSELS. INSPECTION DURING MANUFACTURE.	IIE	3	46 CFR 54.01-5, CLASS II PRESSURE VESSELS, 46 CFR 197.338. ABS SECTION 4. ASME PVHO-1A, 1.3. INSPECTION: 46 CFR 176.05, 176.10, ABS, SECTION C.17.	TIME DEPENDENT.
2.1.01C	UNCONTROLLABLE DESCENT OR ASCENT	IMPROPER OR LACK OF MAINTENANCE TO BALLAST SYSTEM (SEE ALSO 6.4)	INABILITY TO SURFACE OR TO STAY SUBMERGED	IIC	2	PREVENTIVE MAINTENANCE PROGRAM FOR PERIODIC TESTS AND INSPECTIONS OF PRESSURE VESSELS AND PIPING.	IIE	3	46 CFR 197.462. ABS, SECTION B.45. MTS I, SECTION H, MTS II, SECTION J.	TIME DEPENDENT.
2.1.01D	UNCONTROLLABLE DESCENT OR ASCENT	IMPROPER OPERATION OF BALLAST SYSTEM (SEE ALSO 6.1)	INABILITY TO SURFACE OR TO STAY SUBMERGED	IIC	2	PROVIDE PROPER OPERATING PROCEDURES. TRAINING PROGRAM.	IID	2	OP PROC: MTS III, SECTION B.2. TRAINING: MTS I, SECTION I.	TIME DEPENDENT.

ELEMENT: SUBMERSIBLE
SYSTEM: HULL
SUBSYSTEM: EXOSTRUCTURE AND ATTACHMENTS

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
1.3.13	PASSENGER FALLS OFF DECK INTO WATER	NO PROTECTION HAND RAILS OR LIFE LINES PROVIDED ON DECK OR IN TRANSFER AREAS	INJURY, DROWNING	IC	1	PROVIDE HAND RAILS OR LIFE LINES AT ALL AREAS ON DECK WHERE PASSENGERS MAY WALK. PROVIDE HAND RAILS OR LIFE LINES IN TRANSFER AREAS.	IE	3	DECK: 46 CFR 177.35. TRANSFER AREAS: TBD.	

ELEMENT: SUBMERSIBLE
SYSTEM: SHIP CONTROL
SUBSYSTEM: BALLAST AND TRIM

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
2.1.01A	UNCONTROLLABLE DESCENT OR ASCENT	IMPROPER DESIGN, SIZING, OR MATERIAL SELECTION FOR BALLAST SYSTEM	INABILITY TO SURFACE OR TO STAY SUBMERGED	IID	2	FOLLOW CFR, ABS, ASME FOR THE DESIGN AND CONSTRUCTION OF CLASS II PRESSURE VESSELS. FOLLOW MTS FOR DESIGN OF BALLAST SYSTEM. USCG PLAN REVIEW.	IIE	3	46 CFR 54.01-5, CLASS II PRESSURE VESSELS, 46 CFR 159. MTS I, SECTIONS E.4.2 AND A.2.2. ABS, SECTIONS 2.19, 3, & 9. ASME PVHO-1A, 1.2. USCG, MAY 87, P.3.	TIME DEPENDENT
2.1.01B	UNCONTROLLABLE DESCENT OR ASCENT	IMPROPER FABRICATION OR INSTALLATION OF BALLAST SYSTEM	INABILITY TO SURFACE OR TO STAY SUBMERGED	IIC	2	FOLLOW CFR, ASME, AND ABS FOR FABRICATION OF PRESSURE VESSELS. INSPECTION DURING MANUFACTURE.	IIE	3	46 CFR 54.01-5, CLASS II PRESSURE VESSELS, 46 CFR 197.338. ABS SECTION 4. ASME PVHO-1A, 1.3. INSPECTION: 46 CFR 176.05, 176.10, ABS, SECTION C.17.	TIME DEPENDENT
2.1.01C	UNCONTROLLABLE DESCENT OR ASCENT	IMPROPER OR LACK OF MAINTENANCE TO BALLAST SYSTEM (SEE ALSO 6.4)	INABILITY TO SURFACE OR TO STAY SUBMERGED	IIC	2	PREVENTIVE MAINTENANCE PROGRAM FOR PERIODIC TESTS AND INSPECTIONS OF PRESSURE VESSELS AND PIPING.	IIE	3	46 CFR 197.462. ABS, SECTION B.45. MTS I, SECTION H, MTS II, SECTION J.	TIME DEPENDENT
2.1.01D	UNCONTROLLABLE DESCENT OR ASCENT	IMPROPER OPERATION OF BALLAST SYSTEM (SEE ALSO 6.1)	INABILITY TO SURFACE OR TO STAY SUBMERGED	IIC	2	PROVIDE PROPER OPERATING PROCEDURES. TRAINING PROGRAM.	IID	2	OP PROC: MTS III, SECTION B.2. TRAINING: MTS I, SECTION I.	TIME DEPENDENT

ELEMENT: SUBMERSIBLE
SYSTEM: SHIP CONTROL
SUBSYSTEM: BALLAST AND TRIM

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
2.1.01E	UNCONTROLLABLE DESCENT OR ASCENT	LOSS OF PNEUMATIC CONTROL OF BALLAST SYSTEM (SEE ALSO 3.1)	INABILITY TO SURFACE OR TO STAY SUBMERGED	IIC	2	FOLLOW ABS FOR MANUALLY OPERATED ABILITY TO DEBALLAST. PROVIDE REDUNDANT SYSTEMS PER MTS.	IIE	3	ABS, SECTION 2.19. MTS I, SECTION A.2.2.	TIME DEPENDENT
2.1.01F	UNCONTROLLABLE DESCENT OR ASCENT	LOSS OF HYDRAULIC CONTROL OF BALLAST SYSTEM (SEE ALSO 3.2)	INABILITY TO SURFACE OR TO STAY SUBMERGED	IIC	2	MANUALLY OPERATED ABILITY TO DEBALLAST PER ABS. PROVIDE REDUNDANT SYSTEMS PER MTS.	IIE	3	ABS, SECTION 2.19. MTS I, SECTION A.2.2.	TIME DEPENDENT
2.1.01G	UNCONTROLLABLE DESCENT OR ASCENT	LOSS OF ELECTRICAL CONTROL OF BALLAST SYSTEM (SEE ALSO 3.3)	INABILITY TO SURFACE OR TO STAY SUBMERGED	IIC	2	MANUALLY OPERATED ABILITY TO DEBALLAST PER ABS. PROVIDE REDUNDANT SYSTEMS PER MTS.	IIE	3	ABS, SECTION 2.19. MTS I, SECTION A.2.2.	TIME DEPENDENT
2.1.01H	UNCONTROLLABLE DESCENT OR ASCENT	LOSS OF AIR TO BLOW BALLAST TANKS (SEE ALSO 3.1)	INABILITY TO SURFACE OR TO STAY SUBMERGED	IIC	2	EMERGENCY PROCEDURES.	IIE	3	MTS II, SECTION B.4.6.5A.	TIME DEPENDENT
2.1.01I	UNCONTROLLABLE DESCENT OR ASCENT	FAILURE OF BALLAST TANK VENTS OR VALVES	INABILITY TO SURFACE OR TO STAY SUBMERGED	IIC	2	PROVIDE DIVER ACTUATED MANUAL VENT VALVE SUCH THAT DIVER MAY FEED AIR FROM AIR STORAGE SYSTEM TO BLOW AIR BALLAST TANKS, OR SOME OTHER REDUNDANCY.	IIE	3	MTS I, SECTION A.2.2.	TIME DEPENDENT

ELEMENT: SUBMERSIBLE
SYSTEM: SHIP CONTROL
SUBSYSTEM: BALLAST AND TRIM

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
2.1.01J	UNCONTROLLABLE DESCENT OR ASCENT	FAILURE OF WATER PUMP SYSTEM	INABILITY TO SURFACE OR TO STAY SUBMERGED	IIC	2	FOLLOW ABS FOR DESIGN OF PUMPS. SEPARATE WATER BALLAST SYSTEM INTO FORE AND AFT SYSTEMS WHICH ARE INDEPENDENTLY OPERATED, OR SOME OTHER SYSTEM REDUNDANCY PER MTS.	IIE	3	ABS, SECTION 6.5.5. MTS I, SECTION A.2.2.	TIME DEPENDENT.
2.1.01K	UNCONTROLLABLE DESCENT OR ASCENT	FAILURE OF BALLAST TANK (SEE ALSO 1.3.07 AND 8.2.01)	INABILITY TO SURFACE OR TO STAY SUBMERGED	IIC	2	FOLLOW ABS FOR DESIGN AND CONSTRUCTION OF PRESSURE VESSELS.	IIE	3	46 CFR 54.01-5. ABS, SECTIONS 3, 4 & 9.	TIME DEPENDENT.
2.1.02A	UNABLE TO PROPERLY COMPENSATE FOR WEIGHT OF PASSENGERS	IMPROPER DESIGN OR SIZING OF VARIABLE BALLAST SYSTEM	FLOODING THROUGH OPEN HATCH, INABILITY TO SURFACE OR TO STAY SUBMERGED	IIC	2	FOLLOW CFR AND ABS FOR SURFACE BUOYANCY. FOLLOW MTS FOR INHERENT STABILITY. USCG PLAN REVIEW.	IIE	3	46 CFR. ABS, SECTION 2.19.1A. MTS II, SECTION B.3.0. USCG, MAY 87, P.4.	TIME DEPENDENT.
2.1.02B	UNABLE TO PROPERLY COMPENSATE FOR WEIGHT OF PASSENGERS ON BOARD SUB	IMPROPER FABRICATION OF VARIABLE BALLAST SYSTEM	FLOODING THROUGH OPEN HATCH, INABILITY TO SURFACE OR TO STAY SUBMERGED	IIC	2	FOLLOW CFR, ABS, AND ASME FOR FABRICATION. INSPECTION DURING MANUFACTURE.	IIE	3	46 CFR 54, 159. ABS, SECTION 4. ASME PVHO-1A, SECTION 1.3. INSPECTION: 46 CFR 176.05, 176.10, ABS, SECTION C.17.	TIME DEPENDENT.

ELEMENT: SUBMERSIBLE
SYSTEM: SHIP CONTROL
SUBSYSTEM: BALLAST AND TRIM

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
2.1.02C	UNABLE TO PROPERLY COMPENSATE FOR WEIGHT OF PASSENGERS ON BOARD SUB	IMPROPER OR LACK OF MAINTENANCE TO VARIABLE BALLAST SYSTEM (SEE ALSO 6.4)	FLOODING THROUGH OPEN HATCH, INABILITY TO SURFACE OR TO STAY SUBMERGED	IIC	2	PREVENTIVE MAINTENANCE PROGRAM FOR PERIODIC TESTS AND INSPECTIONS OF PRESSURE VESSELS AND PIPING.	IIE	3	46 CFR 197.462. ABS, SECTION B.45. MTS I, SECTION H, MTS II, SECTION J.	TIME DEPENDENT.
2.1.02D	UNABLE TO PROPERLY COMPENSATE FOR WEIGHT OF PASSENGERS ON BOARD SUB	IMPROPER OPERATION OF VARIABLE BALLAST SYSTEM (SEE ALSO 6.1)	FLOODING THROUGH OPEN HATCH, INABILITY TO SURFACE OR TO STAY SUBMERGED	IIC	2	PROVIDE PROPER OPERATING PROCEDURES. TRAINING PROGRAM.	IID	2	OP PROC: MTS III, SECTION B.2. TRAINING: MTS I, SECTION I.	TIME DEPENDENT.
2.1.03A	LOSS OF STABILITY DURING EMERGENCY ASCENT OR NORMAL SUBMERGED OPERATIONS	IMPROPER DESIGN OR MATERIAL SELECTION FOR TRIM SYSTEM	EXCESSIVE ROLL, INJURY DUE TO FALL	IIC	2	FOLLOW USCG, ABS, & MTS FOR SUBMERGED STABILITY, DESIGN, AND MATERIAL SELECTION. FOLLOW MTS FOR INHERENT STABILITY. USCG PLAN REVIEW.	IIE	3	USCG STABILITY GUIDELINES. ABS, SECTION 2.19 & 3. MTS II, SECTION B.3.0. MTS I, SECTIONS A.2.2.1 & E.4.2. USCG, MAY 87, P.4.	TIME DEPENDENT.

ELEMENT: SUBMERSIBLE
SYSTEM: SHIP CONTROL
SUBSYSTEM: BALLAST AND TRIM

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
2.1.03B	LOSS OF STABILITY DURING EMERGENCY ASCENT OR NORMAL SUBMERGED OPERATIONS	TOO FAST OR TOO SLOW RESPONSE TIME FOR TRIM SYSTEM	EXCESSIVE ROLL, INJURY DUE TO FALL	IIC	2	FOLLOW USCG, ABS, AND MTS FOR INHERENT STABILITY. ACCEPTANCE AND PERIODIC TESTING.	IIE	3	USCG STABILITY GUIDELINES. ABS, SECTION 2.19. MTS I, SECTION E.4.2. MAINTENANCE AND TESTING: ABS, SECTION B.45, C.17, MTS I, SECTION H, MTS II, SECTION J, 46 CFR 176.05, 176.10.	TIME DEPENDENT
2.1.03C	LOSS OF STABILITY DURING EMERGENCY ASCENT OR NORMAL SUBMERGED OPERATIONS	IMPROPER FABRICATION OR INSTALLATION OF TRIM SYSTEM	EXCESSIVE ROLL, INJURY DUE TO FALL	IIC	2	FOLLOW USCG STABILITY GUIDELINES. FOLLOW ABS AND ASME FOR FABRICATION. ACCEPTANCE INSPECTION AND TESTING.	IIE	3	USCG STABILITY GUIDELINES. ABS, SECTION 4. ASME PVHO-1A, SECTION 1.3. INSPECTION: 46 CFR 176.05, 176.10, ABS, SECTION C.17.	TIME DEPENDENT
2.1.03D	LOSS OF STABILITY DURING EMERGENCY ASCENT OR NORMAL SUBMERGED OPERATIONS	IMPROPER OR LACK OF MAINTENANCE TO TRIM SYSTEM (SEE ALSO 6.4)	EXCESSIVE ROLL, INJURY DUE TO FALL	IIC	2	FOLLOW USCG STABILITY GUIDELINES. FOLLOW CFR FOR PERIODIC TESTS AND INSPECTIONS OF PRESSURE VESSELS AND PIPING. PREVENTIVE MAINTENANCE PROGRAM.	IIE	3	USCG STABILITY GUIDELINES. 46 CFR 197.462. MAINTENANCE: ABS, SECTION B.45, MTS I, SECTION H, MTS II, SECTION J.	TIME DEPENDENT

ELEMENT: SUBMERSIBLE
SYSTEM: SHIP CONTROL
SUBSYSTEM: BALLAST AND TRIM

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
2.1.03E	LOSS OF STABILITY DURING EMERGENCY ASCENT OR NORMAL SUBMERGED OPERATIONS	IMPROPER OPERATION OF TRIM SYSTEM (SEE ALSO 6.1)	EXCESSIVE ROLL, INJURY DUE TO FALL	IIC	2	FOLLOW USCG STABILITY GUIDELINES. PROVIDE PROPER OPERATING PROCEDURES. TRAINING PROGRAM.	IID	2	USCG STABILITY GUIDELINES. OP PROC: MTS III, SECTION B.2. TRAINING: MTS I, SECTION I.	TIME DEPENDENT
2.1.03F	LOSS OF STABILITY DURING EMERGENCY ASCENT OR NORMAL SUBMERGED OPERATIONS	LOSS OF PNEUMATIC POWER OR CONTROL OF TRIM SYSTEM (SEE ALSO 3.1)	EXCESSIVE ROLL, INJURY DUE TO FALL	IIC	2	FOLLOW USCG AND ABS FOR SUBMERGED STABILITY. INCORPORATE MANUAL MEANS TO CONTROL TRIM SYSTEM, OR SOME OTHER SYSTEM REDUNDANCY.	IIE	3	USCG STABILITY GUIDELINES. ABS, SECTION 2.19. SYSTEM REDUNDANCY: TBD.	TIME DEPENDENT
2.1.03G	LOSS OF STABILITY DURING EMERGENCY ASCENT OR NORMAL SUBMERGED OPERATIONS	LOSS OF HYDRAULIC POWER OR CONTROL TO TRIM SYSTEM (SEE ALSO 3.2)	EXCESSIVE ROLL, INJURY DUE TO FALL	IIC	2	FOLLOW USCG AND ABS FOR SUBMERGED STABILITY. INCORPORATE MANUAL MEANS TO CONTROL TRIM SYSTEM OR SOME OTHER REDUNDANT SYSTEMS.	IIE	2	USCG STABILITY GUIDELINES. ABS, SECTION 2.19 SYSTEM REDUNDANCY: TBD.	TIME DEPENDENT
2.1.03H	LOSS OF STABILITY DURING EMERGENCY ASCENT OR NORMAL SUBMERGED OPERATIONS	LOSS OF ELECTRICAL POWER OR CONTROL TO TRIM SYSTEM (SEE ALSO 3.3)	EXCESSIVE ROLL, INJURY DUE TO FALL	IIC	2	FOLLOW USCG AND ABS FOR SUBMERGED STABILITY. INCORPORATE MANUAL MEANS TO CONTROL TRIM SYSTEM OR SOME OTHER REDUNDANT SYSTEMS.	IIE	3	USCG STABILITY GUIDELINES. ABS, SECTION 2.19. SYSTEM REDUNDANCY: TBD.	TIME DEPENDENT

ELEMENT: SUBMERSIBLE
SYSTEM: SHIP CONTROL
SUBSYSTEM: BALLAST AND TRIM

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
2.1.03I	LOSS OF STABILITY DURING EMERGENCY ASCENT OR NORMAL SUBMERGED OPERATIONS	FAILURE OF TRIM TANKS (SEE ALSO 1.3.02)	EXCESSIVE ROLL, INJURY DUE TO FALL	IIC	2	FOLLOW CFR AND ABS FOR DESIGN AND CONSTRUCTION OF PRESSURE VESSELS.	IIE	3	46 CFR 54. ABS, SECTION 3, 4, & 9.	TIME DEPENDENT.
2.1.03J	LOSS OF STABILITY DURING EMERGENCY ASCENT OR NORMAL SUBMERGED OPERATIONS	PASSENGERS MOVE TO ONE SIDE OR ONE END OF SUB	EXCESSIVE ROLL, INJURY DUE TO FALL	IIB	1	FOLLOW USCG STABILITY GUIDELINES. SUB SHOULD REMAIN POSITIVELY BUOYANT UNDER SUCH EMERGENCY CONDITIONS.	IIC	2	USCG STABILITY GUIDELINES. MTS I, SECTION A.2.2, E.4.2.	TIME DEPENDENT.
2.1.04A	LOSS OF STABILITY DURING NORMAL SURFACE OPERATIONS	IMPROPER DESIGN OR MATERIAL SELECTION FOR TRIM SYSTEM	EXCESSIVE ROLL, INJURY DUE TO FALL, FLOODING	IIC	2	FOLLOW USCG STABILITY GUIDELINES. FOLLOW CFR AND MTS FOR SURFACE STABILITY. USCG PLAN REVIEW.	IIE	3	USCG STABILITY GUIDELINES. 46 CFR 170 & 171. MTS II, SECTION B.3.0. USCG, MAY 87, P.4.	TIME DEPENDENT.
2.1.04B	LOSS OF STABILITY DURING NORMAL SURFACE OPERATIONS	TOO FAST OR TOO SLOW RESPONSE TIME FOR TRIM SYSTEM	EXCESSIVE ROLL, INJURY DUE TO FALL, FLOODING	IIC	2	FOLLOW USCG GUIDELINES, CFR, AND MTS FOR SURFACE STABILITY.	IIE	3	USCG STABILITY GUIDELINES. 46 CFR 170 & 171. MTS I, SECTION E.4.2.	TIME DEPENDENT.
2.1.04C	LOSS OF STABILITY DURING NORMAL SURFACE OPERATIONS	IMPROPER FABRICATION OR INSTALLATION OF TRIM SYSTEM	EXCESSIVE ROLL, INJURY DUE TO FALL, FLOODING	IIC	2	FOLLOW ABS AND ASME FOR FABRICATION. INSPECTION DURING MANUFACTURE.	IIE	3	ABS, SECTION 4. ASME PVHO-1A, SECTION 1.3. INSPECTION: 46 CFR 176.05, 176.10, ABS, SECTION C.17.	TIME DEPENDENT.

ELEMENT: SUBMERSIBLE
SYSTEM: SHIP CONTROL
SUBSYSTEM: BALLAST AND TRIM

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
2.1.04D	LOSS OF STABILITY DURING NORMAL SURFACE OPERATIONS	IMPROPER OR LACK OF MAINTENANCE TO TRIM SYSTEM (SEE ALSO 6.4)	EXCESSIVE ROLL, INJURY DUE TO FALL, FLOODING	IIC	2	PREVENTIVE MAINTENANCE PROGRAM FOR PERIODIC TESTS AND INSPECTIONS OF PRESSURE VESSELS AND PIPING.	IIE	3	46 CFR 176.05, 176.10, AND 197.462, ABS, SECTION B.45, C.17, MTS I, SECTION H, MTS II, SECTION J.	TIME DEPENDENT
2.1.04E	LOSS OF STABILITY DURING NORMAL SURFACE OPERATIONS	IMPROPER OPERATION OF TRIM SYSTEM (SEE ALSO 6.1)	EXCESSIVE ROLL, INJURY DUE TO FALL, FLOODING	IIC	2	PROVIDE PROPER OPERATING PROCEDURES. TRAINING PROGRAM.	IID	2	OP PROC: MTS III, SECTION B.2. TRAINING: MTS I, SECTION I.	TIME DEPENDENT
2.1.04F	LOSS OF STABILITY DURING NORMAL SURFACE OPERATIONS	LOSS OF PNEUMATIC POWER OR CONTROL OF TRIM SYSTEM (SEE ALSO 3.1)	EXCESSIVE ROLL, INJURY DUE TO FALL, FLOODING	IIC	2	INCORPORATE MANUAL MEANS TO CONTROL TRIM SYSTEM OR OTHER REDUNDANT SYSTEMS.	IIE	3	MTS I, SECTION A.2.2.1.	TIME DEPENDENT
2.1.04G	LOSS OF STABILITY DURING NORMAL SURFACE OPERATIONS	LOSS OF HYDRAULIC POWER OR CONTROL TO TRIM SYSTEM (SEE ALSO 3.2)	EXCESSIVE ROLL, INJURY DUE TO FALL, FLOODING	IIC	2	INCORPORATE MANUAL MEANS TO CONTROL TRIM SYSTEM OR OTHER REDUNDANT SYSTEMS.	IIE	3	MTS I, SECTION A.2.2.1.	TIME DEPENDENT
2.1.04H	LOSS OF STABILITY DURING NORMAL SURFACE OPERATIONS	LOSS OF ELECTRICAL POWER OR CONTROL TO TRIM SYSTEM (SEE ALSO 3.3)	EXCESSIVE ROLL, INJURY DUE TO FALL, FLOODING	IIC	2	INCORPORATE MANUAL MEANS TO CONTROL TRIM SYSTEM OR OTHER REDUNDANT SYSTEMS.	IIE	3	MTS I, SECTION A.2.2.1.	TIME DEPENDENT
2.1.04I	LOSS OF STABILITY DURING NORMAL SURFACE OPERATIONS	FAILURE OF TRIM TANKS (SEE ALSO 1.3.02)	EXCESSIVE ROLL, INJURY DUE TO FALL, FLOODING	IIC	2	FOLLOW CFR AND ABS FOR DESIGN AND CONSTRUCTION OF PRESSURE VESSELS.	IIE	3	46 CFR 54.01-5. ABS, SECTION 3, 4, & 9. MTS I, SECTION A.2.2.1.	TIME DEPENDENT

ELEMENT: SUBMERSIBLE
SYSTEM: SHIP CONTROL
SUBSYSTEM: BALLAST AND TRIM

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
2.1.04J	LOSS OF STABILITY DURING NORMAL SURFACE OPERATIONS	PASSENGERS MOVE TO ONE SIDE OR ONE END OF SUB	EXCESSIVE ROLL, INJURY DUE TO FALL, FLOODING	IIB	1	PROVIDE PROPER OPERATING PROCEDURES (SEE SECTION 6.1.). INFORM PASSENGERS OF SAFETY PROCEDURES.	IIC	2	OP PROC: MTS III, SECTION 8.2. SAFETY PROC: TBD.	TIME DEPENDENT

ELEMENT: SUBMERSIBLE
SYSTEM: SHIP CONTROL
SUBSYSTEM: PILOTING

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
2.2.01A	NO PILOTING EQUIPMENT	NO PILOTING EQUIPMENT INSTALLED ON BOARD	COLLISION	IIDC	2	COMPASS PER CFR. AT LEAST ONE COMPASS AND A SONAR PER ABS AND MTS.	IIE	3	46 CFR 184.20. ABS, SECTION 2.21. MTS III, SECTION C.1.4.	
2.2.01B	LOSS OF PILOTING EQUIPMENT	IMPROPER DESIGN OR SELECTION OF PILOTING EQUIPMENT	COLLISION	IIC	2	AT LEAST ONE COMPASS AND A SONAR PER ABS AND MTS. SYSTEM ACCURACY FOR WORST-CASE OR CONDITIONS PER NAVY.	IIE	3	ABS, SECTION 2.21. MTS III, SECTION C.1.4. NAVMAT, B.7.6.	
2.2.01C	LOSS OF PILOTING EQUIPMENT	IMPROPER FABRICATION OR INSTALLATION OF PILOTING EQUIPMENT	COLLISION	IIC	2	INSPECTION DURING FABRICATION. ACCEPTANCE TESTING	IIE	3	46 CFR 176.05, 176.10, ABS, SECTION C.17.	
2.2.01D	LOSS OF PILOTING EQUIPMENT	IMPROPER OR LACK OF MAINTENANCE TO PILOTING EQUIPMENT (SEE ALSO 6.4)	COLLISION	IIC	2	PREVENTIVE MAINTENANCE PROGRAM.	IIE	3	ABS, SECTION B.45, MTS I, SECTION H, MTS II, SECTION J.	
2.2.01E	LOSS OF PILOTING EQUIPMENT	IMPROPER OPERATION OF PILOTING EQUIPMENT (SEE ALSO 6.1)	COLLISION	IIC	2	PROVIDE PROPER OPERATING PROCEDURES. TRAINING PROGRAM.	IID	2	OP PROC: MTS III, SECTION B.2. TRAINING: MTS I, SECTION I.	
2.2.01F	LOSS OF PILOTING EQUIPMENT	LOSS OF ELECTRICAL POWER OR CONTROL TO PILOTING EQUIPMENT (SEE ALSO 3.3)	COLLISION	IIC	2	PROVIDE EMERGENCY POWER TO PILOTING EQUIPMENT AND EMERGENCY PROCEDURES.	IIE	3	EMER POWER: ABS, SECTION 7.27. EMER PROC: MTS III, SECTION B.4.6.4.	

ELEMENT: SUBMERSIBLE
SYSTEM: SHIP CONTROL
SUBSYSTEM: PILOTING

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
2.2.01G	LOSS OF PILOTING EQUIPMENT	MALFUNCTION OF ELECTRONIC EQUIPMENT	COLLISION	IIC	2	SYSTEM REDUNDANCY OR ALTERNATE MEANS OF PILOTING PER NAVY.	IIE	3	NAVMAT B.7.6	
2.2.02A	DESCENDING BELOW CERTIFIED OPERATIONAL DEPTHS	NO DEPTH GAUGE INSTALLED	LEAKAGE/ FLOODING	IIC	2	DEPTH/ALTITUDE ECHO SOUNDER, PRESSURE GAUGE, OR OTHER DEPTH METER PER MTS.	IIE	3	MTS II, B.11.0	TIME/DEPTH DEPENDENT
2.2.02B	DESCENDING BELOW CERTIFIED OPERATIONAL DEPTHS	IMPROPER DESIGN OR SELECTION OF DEPTH GAUGE	LEAKAGE/ FLOODING	IIC	2	DEPTH/ALTITUDE ECHO SOUNDER, PRESSURE GAUGE, OR OTHER DEPTH METER PER MTS.	IIE	3	MTS II, B.11.0	TIME/DEPTH DEPENDENT
2.2.02C	DESCENDING BELOW CERTIFIED OPERATIONAL DEPTHS	IMPROPER FABRICATION OR INSTALLATION OF DEPTH GAUGE	LEAKAGE/ FLOODING	IIC	2	INSPECTION DURING MANUFACTURE. ACCEPTANCE TESTING. GAUGE CERTIFICATION.	IIE	3	INSPECTION/TEST: 46 CFR 176.05, 176.10, ABS C.17. GAUGE CERT: TBD.	TIME/DEPTH DEPENDENT
2.2.02D	DESCENDING BELOW CERTIFIED OPERATIONAL DEPTHS	IMPROPER OR LACK OF MAINTENANCE TO DEPTH GAUGE (SEE ALSO 6.4)	LEAKAGE/ FLOODING	IIC	2	PREVENTIVE MAINTENANCE PROGRAM.	IIE	3	ABS, SECTION B.45, MTS I, SECTION H, MTS II, SECTION J.	TIME/DEPTH DEPENDENT
2.2.02E	DESCENDING BELOW CERTIFIED OPERATIONAL DEPTHS	LOSS OF PNEUMATIC POWER TO DEPTH GAUGE (SEE ALSO 3.1)	LEAKAGE/ FLOODING	IIC	2	PROVIDE INDEPTH MEASUREMENT REDUNDANCY.	IIE	3	TBD.	TIME/DEPTH DEPENDENT
2.2.02F	DESCENDING BELOW CERTIFIED OPERATIONAL DEPTHS	LOSS OF HYDRAULIC POWER TO DEPTH GAUGE (SEE ALSO 3.2)	LEAKAGE/ FLOODING	IIC	2	PROVIDE SYSTEM REDUNDANCY.	IIE	3	MTS III, SECTION C.1.3.	TIME/DEPTH DEPENDENT

ELEMENT: SUBMERSIBLE
SYSTEM: SHIP CONTROL
SUBSYSTEM: PILOTING

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
2.2.02G	DESCENDING BELOW CERTIFIED OPERATIONAL DEPTHS	LOSS OF ELECTRICAL POWER TO DEPTH GAUGE (SEE ALSO 3.3)	LEAKAGE/ FLOODING	IIC	2	FOLLOW MTS TO PROVIDE EMERGENCY ELECTRICAL POWER TO DEPTH GAUGE. PROVIDE SYSTEM REDUNDANCY.	IIE	3	MTS II, SECTION B.13.0. MTS III, SECTION C.1.3.	TIME/DEPTH DEPENDENT
2.2.02H	DESCENDING BELOW CERTIFIED OPERATIONAL DEPTHS	MALFUNCTION OF DEPTH GAUGE	LEAKAGE/ FLOODING	IIC	2	PROVIDE SYSTEM REDUNDANCY.	IIE	3	MTS III, SECTION C.1.3.	TIME/DEPTH DEPENDENT
2.2.02I	DESCENDING BELOW CERTIFIED OPERATIONAL DEPTHS	IMPROPER OPERATION OF DEPTH GAUGE (SEE ALSO 6.1)	LEAKAGE/ FLOODING	IIC	2	PROVIDE PROPER OPERATING PROCEDURES. TRAINING PROGRAM.	IID	2	OP PROC: MTS III, SECTION B.2. TRAINING: MTS I, SECTION I.	TIME/DEPTH DEPENDENT
2.2.03A	AUTOMATIC PILOT FAILS TO ACCURATELY GUIDE SUB	IMPROPER DESIGN OF AUTOMATIC PILOT	COLLISION	IIC	2	CERTIFICATION PROGRAM.	IIE	3	TBD.	
2.2.03B	AUTOMATIC PILOT FAILS TO ACCURATELY GUIDE SUB	IMPROPER INSTALLATION OF AUTOMATIC PILOT	COLLISION	IIC	2	INSPECTION DURING INSTALLATION.	IIE	3	46 CFR 176.05, 176.10, ABS, SECTION C.17.	
2.2.03C	AUTOMATIC PILOT FAILS TO ACCURATELY GUIDE SUB	IMPROPER OR LACK OF MAINTENANCE TO AUTOMATIC PILOT (SEE ALSO 6.4)	COLLISION	IIC	2	PREVENTIVE MAINTENANCE PROGRAM.	IIE	3	ABS, SECTION B.45, MTS I, SECTION H, MTS II, SECTION J.	
2.2.03D	AUTOMATIC PILOT FAILS TO ACCURATELY GUIDE SUB	IMPROPER OPERATION OF AUTOMATIC PILOT (SEE ALSO 6.1)	COLLISION	IIC	2	PROVIDE PROPER OPERATING PROCEDURES. FOLLOW CFR AND MANUFACTURER FOR OPERATION OF AUTO PILOT. TRAINING PROGRAM.	IID	2	OP PROC: MTS III, SECTION B.2. 46 CFR 185.20-30, 33 CFR 164.15. TRAINING: MTS , SECTION I.	

ELEMENT: SUBMERSIBLE
SYSTEM: SHIP CONTROL
SUBSYSTEM: PILOTING

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
2.2.03E	AUTOMATIC PILOT FAILS TO ACCURATELY GUIDE SUB	MALFUNCTION OF AUTOMATIC PILOT	COLLISION	IIC	2	FOLLOW CFR AS TO USE OF AUTO PILOT. REQUIRE INSTALLATION OF ALARM SYSTEMS.	IIE	3	46 CFR 113, 185.20-30. ALARM: TBD.	

ELEMENT: SUBMERSIBLE
SYSTEM: SHIP CONTROL
SUBSYSTEM: PROPULSION AND MANEUVERING

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
2.3.01A	INABILITY TO MOVE FORWARD AND AFT	IMPROPER DESIGN, SIZING, OR MATERIAL SELECTION FOR HORIZONTAL PROPULSION SYSTEM	COLLISION	IIC	2	FOLLOW ABS AND MTS FOR PROPULSION SHAFTING. USCG PLAN REVIEW.	IIE	3	ABS, SECTION 6.11. MTS II, SECTION B.10.0. USCG, MAY 87, P.4.	
2.3.01B	INABILITY TO MOVE FORWARD AND AFT	IMPROPER FABRICATION OR INSTALLATION OF HORIZONTAL PROPULSION SYSTEM	COLLISION	IIC	2	FOLLOW ABS AND MTS FOR PROPULSION SHAFTING. INSPECTION DURING MANUFACTURE.	IIE	3	ABS, SECTION 6.11. MTS II, SECTION B.10.0. INSPECTION: 46 CFR 176.05, 176.10," ABS C.17.	
2.3.01C	INABILITY TO MOVE FORWARD AND AFT	IMPROPER OR LACK OF MAINTENANCE TO HORIZONTAL PROPULSION SYSTEM (SEE ALSO 6.4)	COLLISION	IIC	2	PREVENTIVE MAINTENANCE PROGRAM, TO INCLUDE INSPECTIONS FOR OIL CONTAMINATION, CORROSION, LOOSE FITTINGS, AND SYSTEM INTEGRITY.	IIE	3	ABS, SECTION B.45, MTS I, SECTION H, MTS II, SECTION J.	
2.3.01D	INABILITY TO MOVE FORWARD AND AFT	IMPROPER OPERATION OF HORIZONTAL PROPULSION SYSTEM (SEE ALSO 6.1)	COLLISION	IIC	2	PROVIDE PROPER OPERATING PROCEDURES. TRAINING PROGRAM.	IID	2	OP PROC: MTS III, SECTION B.2. TRAINING: MTS I, SECTION I.	
2.3.01E	INABILITY TO MOVE FORWARD AND AFT	LOSS OF PNEUMATIC POWER OR CONTROL TO HORIZONTAL PROPULSION SYSTEM (SEE ALSO 3.1)	COLLISION	IIC	2	PROVIDE SYSTEM REDUNDANCY, SUCH AS SEPARATION OF PORT AND STARBOARD SYSTEMS.	IIE	3	TBD	

ELEMENT: SUBMERSIBLE
SYSTEM: SHIP CONTROL
SUBSYSTEM: PROPULSION AND MANEUVERING

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
2.3.01F	INABILITY TO MOVE FORWARD AND AFT	LOSS OF HYDRAULIC POWER OR CONTROL TO HORIZONTAL PROPULSION SYSTEM (SEE ALSO 3.2)	COLLISION	IIC	2	PROVIDE SYSTEM REDUNDANCY, SUCH AS SEPARATION OF PORT AND STARBOARD SYSTEMS.	IIE	3	TBD	
2.3.01G	INABILITY TO MOVE FORWARD AND AFT	LOSS OF ELECTRICAL POWER OR CONTROL TO HORIZONTAL PROPULSION SYSTEM (SEE ALSO 3.3)	COLLISION	IIC	2	PROVIDE SYSTEM REDUNDANCY, SUCH AS SEPARATION OF PORT AND STARBOARD SYSTEMS.	IIE	3	TBD	
2.3.01H	INABILITY TO MOVE FORWARD AND AFT	COMPONENT OF HORIZONTAL PROPULSION SYSTEM BECOMES ENTANGLED WITH OBSTACLE (SEE ALSO 8.4.01)	COLLISION, INABILITY TO SURFACE	IIB	1	FOLLOW MTS FOR PROTECTING PROPELLERS. PROVIDE PROPER OPERATING PROCEDURES.	IIC	2	MTS II, SECTION B.10.0. OP PROC: MTS III, SECTION B.2.	TIME DEPENDENT.
2.3.01I	INABILITY TO MOVE FORWARD AND AFT	MALFUNCTION OF HORIZONTAL PROPULSION SYSTEM	COLLISION	IIC	2	PROVIDE SYSTEM REDUNDANCY.	IIE	3	TBD	
2.3.02A	INABILITY TO MOVE VERTICALLY	IMPROPER DESIGN, SIZING, OR MATERIAL SELECTION FOR VERTICAL PROPULSION SYSTEM	INABILITY TO SUBMERGE, STAY SUBMERGED, OR SURFACE	IIC	2	FOLLOW ABS AND MTS FOR PROPULSION SHAFTING. ACCEPTANCE TESTING. USCG PLAN REVIEW.	IIE	3	ABS, SECTION 6.11. MTS II, SECTION B.10.0. TEST: ABS, SECTION C.17. USCG, MAY 87, P.4.	TIME DEPENDENT.

ELEMENT: SUBMERSIBLE
SYSTEM: SHIP CONTROL
SUBSYSTEM: PROPULSION AND MANEUVERING

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
2.3.02B	INABILITY TO MOVE VERTICALLY	IMPROPER FABRICATION OR INSTALLATION OF VERTICAL PROPULSION SYSTEM	INABILITY TO SUBMERGE, STAY SUBMERGED, OR SURFACE	IIC	2	FOLLOW ABS, CFR AND MTS FOR PROPULSION SHAFTING. INSPECTION DURING MANUFACTURE.	IIE	3	ABS, SECTION 6.11. MTS II, SECTION B.10.0. 46 CFR 182.05. INSPECTION: 46 CFR 176.05, 176.10, ABS, SECTION C.17.	TIME DEPENDENT
2.3.02C	INABILITY TO MOVE VERTICALLY	IMPROPER OR LACK OF MAINTENANCE TO VERTICAL PROPULSION SYSTEM (SEE ALSO 6.4)	INABILITY TO SUBMERGE, STAY SUBMERGED, OR SURFACE	IIC	2	PREVENTIVE MAINTENANCE PROGRAM TO INCLUDE INSPECTION OF THRUSTER BEARINGS REGULARLY.	IIE	3	ABS, SECTION B.45, MTS I, SECTION H, MTS II, SECTION J.	TIME DEPENDENT
2.3.02D	INABILITY TO MOVE VERTICALLY	IMPROPER OPERATION OF VERTICAL PROPULSION SYSTEM (SEE ALSO 6.1)	INABILITY TO SUBMERGE, STAY SUBMERGED, OR SURFACE	IIC	2	PROVIDE PROPER OPERATING PROCEDURES. TRAINING PROGRAM.	IID	2	OP PROC: MTS III, SECTION B.2. TRAINING: MTS I, SECTION I.	TIME DEPENDENT
2.3.02E	INABILITY TO MOVE VERTICALLY	LOSS OF PNEUMATIC POWER OR CONTROL TO VERTICAL PROPULSION SYSTEM (SEE ALSO 3.1)	INABILITY TO SUBMERGE, STAY SUBMERGED, OR SURFACE	IIC	2	PROVIDE SYSTEM REDUNDANCY.	IIE	3	TBD	TIME DEPENDENT
2.3.02F	INABILITY TO MOVE VERTICALLY	LOSS OF HYDRAULIC POWER OR CONTROL TO VERTICAL PROPULSION SYSTEM (SEE ALSO 3.2)	INABILITY TO SUBMERGE, STAY SUBMERGED, OR SURFACE	IIC	2	PROVIDE SYSTEM REDUNDANCY.	IIE	3	TBD	TIME DEPENDENT

ELEMENT: SUBMERSIBLE
SYSTEM: SHIP CONTROL
SUBSYSTEM: PROPULSION AND MANEUVERING

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
2.3.02G	INABILITY TO MOVE VERTICALLY	LOSS OF ELECTRICAL POWER OR CONTROL TO VERTICAL PROPULSION SYSTEM (SEE ALSO 3.3)	INABILITY TO SUBMERGE, STAY SUBMERGED, OR SURFACE	IIC	2	PROVIDE SYSTEM REDUNDANCY.	IIE	3	TBD	TIME DEPENDENT.
2.3.02H	INABILITY TO MOVE VERTICALLY	COMPONENT OF VERTICAL PROPULSION SYSTEM BECOMES ENTANGLED WITH OBSTACLE	INABILITY TO SUBMERGE, STAY SUBMERGED, OR SURFACE	IIC	2	FOLLOW MTS TO PROVIDE PROTECTION TO COMPONENTS OF PROPULSION SYSTEM. PROVIDE PROPER OPERATING PROCEDURES.	IID	2	MTS II, SECTION B.10.0.	TIME DEPENDENT.
2.3.02I	INABILITY TO MOVE VERTICALLY	MALFUNCTION OF VERTICAL PROPULSION SYSTEM	INABILITY TO SUBMERGE, STAY SUBMERGED, OR SURFACE	IIC	2	PROVIDE SYSTEM REDUNDANCY.	IIE	3	TBD	TIME DEPENDENT.
2.3.03A	INABILITY TO MANEUVER PORT OR STARBOARD	IMPROPER DESIGN, SIZING, OR MATERIAL SELECTION FOR MANEUVERING SYSTEM	COLLISION	IIC	2	FOLLOW CFR AND MTS FOR MANEUVERING SYSTEMS. USCG PLAN REVIEW.	IIE	3	46 CFR 182.30. MTS II, SECTION B.10.0. USCG, MAY 87, P.4.	
2.3.03B	INABILITY TO MANEUVER PORT OR STARBOARD	IMPROPER FABRICATION OR INSTALLATION OF MANEUVERING STEERING SYSTEM	COLLISION	IIC	2	FOLLOW CFR AND MTS FOR MANEUVERING SYSTEMS. INSPECTION DURING MANUFACTURE.	IIE	3	46 CFR 182.30. MTS II, SECTION B.10.0., INSPECTION: 46 CFR 176.05. 176.10, ABS, SECTION C.17.	

ELEMENT: SUBMERSIBLE
SYSTEM: SHIP CONTROL
SUBSYSTEM: PROPULSION AND MANEUVERING

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
2.3.03C	INABILITY TO MANEUVER PORT OR STARBOARD	IMPROPER OR LACK OF MAINTENANCE TO MANEUVERING SYSTEM (SEE ALSO 6.4)	COLLISION	IIC	2	FOLLOW CFR TO TEST STEERING GEAR DAILY PRIOR TO GETTING UNDER WAY. PREVENTIVE MAINTENANCE PROGRAM.	IIE	3	46 CFR 185.20-10. MAINTENANCE: ABS, SECTION B.45, MTS I, SECTION H, MTS II, SECTION J.	
2.3.03D	INABILITY TO MANEUVER PORT OR STARBOARD	IMPROPER OPERATION OF MANEUVERING SYSTEM (SEE ALSO 6.1)	COLLISION	IIC	2	PROVIDE PROPER OPERATING PROCEDURES. TRAINING PROGRAM.	IID	2	OP PROC: MTS III, SECTION B.2. TRAINING: MTS I, SECTION I.	
2.3.03E	INABILITY TO MANEUVER PORT OR STARBOARD	LOSS OF PNEUMATIC POWER OR CONTROL TO MANEUVERING SYSTEM (SEE ALSO 3.1)	COLLISION	IIC	2	PROVIDE SYSTEM REDUNDANCY, SUCH AS SEPARATION OF PORT AND STARBOARD SYSTEMS.	IIE	3	TBD	
2.3.03F	INABILITY TO MANEUVER PORT OR STARBOARD	LOSS OF HYDRAULIC POWER OR CONTROL TO MANEUVERING SYSTEM (SEE ALSO 3.2)	COLLISION	IIC	2	PROVIDE SYSTEM REDUNDANCY, SUCH AS SEPARATION OF PORT AND STARBOARD SYSTEMS.	IIE	3	TBD	
2.3.03G	INABILITY TO MANEUVER PORT OR STARBOARD	LOSS OF ELECTRICAL POWER OR CONTROL TO MANEUVERING SYSTEM (SEE ALSO 3.3)	COLLISION	IIC	2	PROVIDE EMERGENCY ELECTRICAL POWER TO STEERING OR MANUAL SYSTEM. PROVIDE SYSTEM REDUNDANCY, SUCH AS SEPARATION OF PORT AND STARBOARD SYSTEMS.	IIE	3	EMER POWER: ABS, SECTION 7.27. REDUNDANCY: TBD.	

ELEMENT: SUBMERSIBLE
SYSTEM: SHIP CONTROL
SUBSYSTEM: PROPULSION AND MANEUVERING

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
2.3.03H	INABILITY TO MANEUVER PORT OR STARBOARD	COMPONENT OF MANEUVERING SYSTEM BECOMES ENTANGLED WITH OBSTACLE	COLLISION, INABILITY TO SURFACE	IIC	2	FOLLOW MTS TO PROVIDE PROTECTION TO COMPONENTS OF STEERING SYSTEM. PROVIDE PROPER OPERATING *PROCEDURES*.	IID	2	MTS II, SECTION B.10.0. CP PROC: MTS III, SECTION B.2.	TIME DEPENDENT
2.3.03I	INABILITY TO MANEUVER PORT OR STARBOARD	MALFUNCTION OF STEERING SYSTEM	COLLISION	IIC	2	PROVIDE SYSTEM REDUNDANCY, SUCH AS SEPARATION OF PORT AND STARBOARD SYSTEMS.	IIE	3	TBD	

ELEMENT: SUBMERSIBLE
SYSTEM: SYSTEMS
SUBSYSTEM: AIR

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
3.1.01A	INSUFFICIENT QUANTITY OR PRESSURIZATION OF AIR SYSTEM FOR OPERATION OF BALLAST SYSTEM, VALVE CONTROL, ETC.	IMPROPER DESIGN, SIZING, OR MATERIAL SELECTION FOR AIR SYSTEM	INABILITY TO SURFACE	IIC	2	FOLLOW CFR, ABS, AND MTS FOR PNEUMATIC SYSTEMS.	IIE	3	46 CFR 58.30, 159. ABS, SECTION 6. MTS II, SECTION B.7.0.	TIME DEPENDENT
3.1.01B	INSUFFICIENT QUANTITY OR PRESSURIZATION OF AIR SYSTEM FOR OPERATION OF BALLAST SYSTEM, VALVE CONTROL, ETC.	IMPROPER FABRICATION OR INSTALLATION OF AIR SYSTEM	INABILITY TO SURFACE	IIC	2	FOLLOW CFR, ABS, AND MTS FOR PNEUMATIC SYSTEMS. INSPECTION DURING MANUFACTURE.	IIE	3	46 CFR 58.30. ABS, SECTION 6. MTS II, SECTION B.7.0. INSPECTION: 46 CFR 176.05, 176.10, ABS, SECTION C.17.	TIME DEPENDENT
3.1.01C	INSUFFICIENT QUANTITY OR PRESSURIZATION OF AIR SYSTEM FOR OPERATION OF BALLAST SYSTEM, VALVE CONTROL, ETC.	IMPROPER OR LACK TO MAINTENANCE TO AIR SYSTEM (SEE ALSO 6.4)	INABILITY TO SURFACE	IIC	2	PREVENTIVE MAINTENANCE PROGRAM.	IID	2	ABS, SECTION B.45, MTS I, SECTION H, MTS II, SECTION J.	TIME DEPENDENT
3.1.01D	INSUFFICIENT QUANTITY OR PRESSURIZATION OF AIR SYSTEM FOR OPERATION OF BALLAST SYSTEM, VALVE CONTROL, ETC.	IMPROPER OPERATION OF AIR SYSTEM (SEE ALSO 6.1)	INABILITY TO SURFACE	IIC	2	PROVIDE PROPER OPERATING PROCEDURES. TRAINING PROGRAM.	IID	2	OP PROC: MTS III, SECTION B.2. TRAINING: MTS I, SECTION I.	TIME DEPENDENT

ELEMENT: SUBMERSIBLE
SYSTEM: SYSTEMS
SUBSYSTEM: AIR

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
3.1.01E	INSUFFICIENT QUANTITY OR PRESSURIZATION OF AIR SYSTEM FOR OPERATION OF BALLAST SYSTEM, VALVE CONTROL, ETC.	FAILURE OF AIR STORAGE CYLINDERS (SEE ALSO 1.3.01)	INABILITY TO SURFACE	IIC	2	USE DOT APPROVED PORTABLE PRESSURE VESSELS.	IIE	3	46 CFR 147.04	TIME DEPENDENT
3.1.01F	INSUFFICIENT QUANTITY OR PRESSURIZATION OF AIR SYSTEM FOR OPERATION OF BALLAST SYSTEM, VALVE CONTROL, ETC.	LOSS OF HYDRAULIC POWER OR CONTROL TO AIR SYSTEM (SEE ALSO 3.2)	INABILITY TO SURFACE	IIC	2	PROVIDE SYSTEM REDUNDANCY. PROVIDE MANUAL MEANS TO SURFACE.	IIE	3	TBD	TIME DEPENDENT
3.1.01G	INSUFFICIENT QUANTITY OR PRESSURIZATION OF AIR SYSTEM FOR OPERATION OF BALLAST SYSTEM, VALVE CONTROL, ETC.	LOSS OF ELECTRICAL POWER OR CONTROL TO AIR SYSTEM (SEE ALSO 3.3)	INABILITY TO SURFACE	IIC	2	PROVIDE EMERGENCY ELECTRICAL POWER TO ENSURE SURFACING. PROVIDE SYSTEM REDUNDANCY.	IIE	3	EMER POWER: ABS, SECTION 7.27. REDUNDANCY: TBD	TIME DEPENDENT
3.1.01H	INSUFFICIENT QUANTITY OR PRESSURIZATION OF AIR SYSTEM FOR OPERATION OF BALLAST SYSTEM, VALVE CONTROL, ETC.	MALFUNCTION OF AIR SYSTEM	INABILITY TO SURFACE	IIC	2	PROVIDE SYSTEM REDUNDANCY. EMERGENCY PROCEDURES.	IIE	3	REDUNDANCY: TBD. MTS III, SECTION 4.6.5A.	TIME DEPENDENT
3.1.01I	INSUFFICIENT QUANTITY OR PRESSURIZATION OF AIR SYSTEM FOR OPERATION OF BALLAST SYSTEM, VALVE CONTROL, ETC.	LEAKAGE OF AIR SYSTEM	INABILITY TO SURFACE	IIC	2	INSTALL METER OR ALARM TO DETECT PRESSURE LOSS IN AIR SYSTEM	IIE	3	TBD	TIME DEPENDENT

ELEMENT: SUBMERSIBLE
SYSTEM: SYSTEMS
SUBSYSTEM: AIR

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
3.1.02	EXPLOSION OF PRESSURE VESSELS FOR AIR SYSTEM	OVERPRESSURIZATION DURING RECHARGING OPERATIONS	INABILITY TO SURFACE, INJURY	IIC	2	PROVIDE MECHANICAL CONTROLS TO PREVENT OVER-PRESSURIZATION. ENFORCE CAREFUL CONTROL OVER MAINTENANCE PROCEDURES.	IIE	3	TBD	TIME DEPENDENT
3.1.03	EXPLOSION OF LOW OR HIGH PRESSURE AIR LINES	OVERPRESSURIZATION OF AIR LINES DUE TO MALFUNCTION OR DESIGN ERRORS	INJURY, INABILITY TO SURFACE	IIC	2	ENSURE ALL PIPING IS OF NECESSARY RATINGS. PROVIDE SYSTEM REDUNDANCY FOR AIR SYSTEM, SUCH AS SEPARATION OF PORT & STARBOARD SYSTEMS.	IIE	3	46 CFR 58.30	TIME DEPENDENT

ELEMENT: SUBMERSIBLE
SYSTEM: SYSTEMS
SUBSYSTEM: AIR

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
3.1.01A	INSUFFICIENT QUANTITY OR PRESSURIZATION OF AIR SYSTEM FOR OPERATION OF BALLAST SYSTEM, VALVE CONTROL, ETC.	IMPROPER DESIGN, SIZING, OR MATERIAL SELECTION FOR AIR SYSTEM	INABILITY TO SURFACE	IIC	2	FOLLOW ABS, AND MTS FOR PNEUMATIC SYSTEMS.	IIE	3	46 CFR 58.30. ABS, SECTION 6. MTS II, SECTION B.7.0.	TIME DEPENDENT.
3.1.01B	INSUFFICIENT QUANTITY OR PRESSURIZATION OF AIR SYSTEM FOR OPERATION OF BALLAST SYSTEM, VALVE CONTROL, ETC.	IMPROPER FABRICATION OR INSTALLATION OF AIR SYSTEM	INABILITY TO SURFACE	IIC	2	FOLLOW CFR, ABS, AND MTS FOR PNEUMATIC SYSTEMS. INSPECTION DURING MANUFACTURE.	IIE	3	46 CFR 58.30. ABS, SECTION 6. MTS II, SECTION B.7.0. INSPECTION: 46 CFR 176.05, 176.10, ABS, SECTION C.17.	TIME DEPENDENT.
3.1.01C	INSUFFICIENT QUANTITY OR PRESSURIZATION OF AIR SYSTEM FOR OPERATION OF BALLAST SYSTEM, VALVE CONTROL, ETC.	IMPROPER OR LACK TO MAINTENANCE TO AIR SYSTEM (SEE ALSO 6.4)	INABILITY TO SURFACE	IIC	2	PREVENTIVE MAINTENANCE PROGRAM.	IID	2	ABS, SECTION B.45, MTS I, SECTION H, MTS II, SECTION J.	TIME DEPENDENT.
3.1.01D	INSUFFICIENT QUANTITY OR PRESSURIZATION OF AIR SYSTEM FOR OPERATION OF BALLAST SYSTEM, VALVE CONTROL, ETC.	IMPROPER OPERATION OF AIR SYSTEM (SEE ALSO 6.1)	INABILITY TO SURFACE	IIC	2	PROVIDE PROPER OPERATING PROCEDURES. TRAINING PROGRAM.	IID	2	OP PROC: MTS III, SECTION B.2. TRAINING: MTS I, SECTION I.	TIME DEPENDENT

ELEMENT: SUBMERSIBLE
SYSTEM: SYSTEMS
SUBSYSTEM: HYDRAULIC

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
3.2.01F	INSUFFICIENT PRESSURIZATION OF HYDRAULIC SYSTEM FOR OPERATION OF VALVES, CONTROLS, ETC.	LOSS OF ELECTRICAL POWER OR CONTROL TO HYDRAULIC SYSTEM (SEE ALSO 3.3)	COLLISION, INABILITY TO SURFACE	IIC	2	PROVIDE PARALLEL SYSTEMS. PROVIDE MANUAL CONTROL TO ESSENTIAL SYSTEMS AND TO ENSURE SURFACING.	IIE	3	MTS I, SECTION E.4.3.	TIME DEPENDENT
3.2.01G	INSUFFICIENT PRESSURIZATION OF HYDRAULIC SYSTEM FOR OPERATION OF VALVES, CONTROLS, ETC.	MALFUNCTION OF HYDRAULIC SYSTEM	COLLISION, INABILITY TO SURFACE	IIC	2	FOLLOW MTS FOR PARALLEL SYSTEMS. EMERGENCY PROCEDURES.	IIE	3	MTS I, SECTION E.4.3. EMER PROC: MTS III, SECTION B.4.7.4.	TIME DEPENDENT
3.2.02	HYDRAULIC FLUID LEAK INTERNAL TO SUB	DAMAGE TO HYDRAULIC SYSTEM COMPONENT	INJURY DUE TO FALL, AIR CONTAMINATION.	IIC	2	FOLLOW MTS IN CHOOSING NON-TOXIC FLUID WITH ACCEPTABLE FLASH AND FIRE POINTS. PROVIDE PROPER OPERATING PROCEDURES.	IID	2	MTS II, SECTION B.7.0. OP PROC: MTS III, SECTION B.2.	TIME DEPENDENT

ELEMENT: SUBMERSIBLE
SYSTEM: SYSTEMS
SUBSYSTEM: ELECTRICAL

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
3.3.01A	LOSS OF ELECTRICAL POWER TO LIGHTS OR TO CONTROLS FOR LIFE SUPPORT, PROPULSION, BALLAST AND TRIM, OR OTHER SYSTEMS	IMPROPER DESIGN, SIZING, OR MATERIAL SELECTION OF ELECTRICAL SYSTEM	INABILITY TO SURFACE, AIR CONTAMINATION, COLLISION	IIC	2	FOLLOW CFR, ABS, MTS, AND NAVY FOR ELECTRICAL INSTALLATIONS AND BATTERIES.	IIE	3	46 CFR 111, 183. ABS, SECTION 7. MTS II, SECTION B.9.0. NAVMAT P-9290, SECTION B.6.	TIME DEPENDENT.
3.3.01B	LOSS OF ELECTRICAL POWER TO LIGHTS OR TO CONTROLS FOR LIFE SUPPORT, PROPULSION, BALLAST AND TRIM, OR OTHER SYSTEMS	IMPROPER FABRICATION OR INSTALLATION OF ELECTRICAL SYSTEM	INABILITY TO SURFACE, AIR CONTAMINATION, COLLISION	IIC	2	FOLLOW CFR, ABS, MTS, AND NAVY FOR ELECTRICAL INSTALLATIONS AND BATTERIES. INSPECTION DURING MANUFACTURE.	IIE	3	46 CFR 111, 183. ABS, SECTION 7. MTS II, SECTION B.9.0. NAVMAT P-9290, SECTION B.6. INSPECTION: 46 CFR 176.05, 176.10, ABS, SECTION C.17.	TIME DEPENDENT.
3.3.01C	LOSS OF ELECTRICAL POWER TO LIGHTS OR TO CONTROLS FOR LIFE SUPPORT, PROPULSION, BALLAST AND TRIM, OR OTHER SYSTEMS	IMPROPER OR LACK OF MAINTENANCE TO ELECTRICAL SYSTEM (SEE ALSO 6.4)	INABILITY TO SURFACE, AIR CONTAMINATION, COLLISION	IIC	2	PREVENTIVE MAINTENANCE PROGRAM, TO INCLUDE INSPECTION OF EXTERIOR CABLE INSULATION AND CONNECTIONS REGULARLY.	IIE	3	ABS, SECTION B.45, MTS I, SECTION H, MTS II, SECTION J.	TIME DEPENDENT.
3.3.01D	LOSS OF ELECTRICAL POWER TO LIGHTS OR TO CONTROLS FOR LIFE SUPPORT, PROPULSION, BALLAST AND TRIM, OR OTHER SYSTEMS	IMPROPER OPERATION OF ELECTRICAL SYSTEM (SEE ALSO 6.1)	INABILITY TO SURFACE, AIR CONTAMINATION, COLLISION	IIC	2	PROVIDE PROPER OPERATING PROCEDURES. TRAINING PROGRAM.	IID	2	OP PROC: MTS III, SECTION B.2. TRAINING: MTS I, SECTION I.	TIME DEPENDENT.

ELEMENT: SUBMERSIBLE
SYSTEM: SYSTEMS
SUBSYSTEM: ELECTRICAL

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
3.3.01E	LOSS OF ELECTRICAL POWER TO LIGHTS OR TO CONTROLS FOR LIFE SUPPORT, PROPULSION, BALLAST AND TRIM, OR OTHER SYSTEMS	OVERLOAD OR SHORT CIRCUIT IN INTERIOR ELECTRICAL WIRING	INABILITY TO SURFACE, AIR CONTAMINATION, COLLISION, FIRE	IIC	2	FOLLOW CFR, ABS, AND MTS FOR SHORT AND FAULT CIRCUIT PROTECTION TO PREVENT OVERLOAD.	IIE	3	46 CFR 183.10 & 111.05. ABS, SECTION 7.11. MTS II, SECTION B.9.0.	TIME DEPENDENT
3.3.01F	LOSS OF ELECTRICAL POWER TO LIGHTS OR TO CONTROLS FOR LIFE SUPPORT, PROPULSION, BALLAST AND TRIM, OR OTHER SYSTEMS	DAMAGE TO OR FAILURE OF BATTERY	INABILITY TO SURFACE, AIR CONTAMINATION, COLLISION	IIC	2	FOLLOW CFR AND ABS FOR EMERGENCY ELECTRICAL POWER. PROVIDE PROPER OPERATING PROCEDURES. PROVIDE SYSTEM REDUNDANCY.	IID	2	46 CFR 111, 112. ABS, SECTIONS 7.25 & 7.27. OP PROC: MTS III, SECTION B.2. REDUNDANCY: TBD.	TIME DEPENDENT
3.3.01G	LOSS OF ELECTRICAL POWER TO LIGHTS OR TO CONTROLS FOR LIFE SUPPORT, PROPULSION, BALLAST AND TRIM, OR OTHER SYSTEMS	INSUFFICIENT CHARGE ON BATTERIES	INABILITY TO SURFACE, AIR CONTAMINATION, COLLISION	IIC	2	PROVIDE LOW CHARGE INDICATOR PER USCG. PROVIDE PROPER MAINTENANCE PROCEDURES. TRAINING PROGRAM.	IID	2	USCG, MAY 87, P.2. MAINTENANCE: ABS, SECTION B.45, MTS I, SECTION H, MTS II, SECTION J. TRAINING: MTS I, SECTION I.	TIME DEPENDENT
3.3.01H	LOSS OF ELECTRICAL POWER TO LIGHTS OR TO CONTROLS FOR LIFE SUPPORT, PROPULSION, BALLAST AND TRIM, OR OTHER SYSTEMS	EXCESSIVE TRIM ANGLE SPILLS ACID TO SHORT OUT BATTERY	INABILITY TO SURFACE, AIR CONTAMINATION, COLLISION	IID	2	FOLLOW CFR AND MTS FOR DESIGN OF BATTERY SYSTEM AT MAXIMUM ANGLE	IIE	3	46 CFR 111.15-2. MTS II, SECTION B.8.0.	TIME DEPENDENT

ELEMENT: SUBMERSIBLE
SYSTEM: SYSTEMS
SUBSYSTEM: ELECTRICAL

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
3.3.01I	LOSS OF ELECTRICAL POWER TO LIGHTS OR TO CONTROLS FOR LIFE SUPPORT, PROPULSION, BALLAST AND TRIM, OR OTHER SYSTEMS	EXCESSIVE HUMIDITY SHORTS ELECTRICAL COMPONENTS	INABILITY TO SURFACE, AIR CONTAMINATION, COLLISION	IIB	1	FOLLOW ABS TO DESIGN ELECTRICAL INSTALLATIONS FOR 100% HUMIDITY. PROVIDE ADEQUATE HUMIDITY CONTROL.	IID	2	ABS, SECTION 7.9. HUMIDITY: TBD.	TIME DEPENDENT
3.3.01J	LOSS OF ELECTRICAL POWER TO LIGHTS OR TO CONTROLS FOR LIFE SUPPORT, PROPULSION, BALLAST AND TRIM, OR OTHER SYSTEMS	MALFUNCTION OF ELECTRICAL SYSTEM	INABILITY TO SURFACE, AIR CONTAMINATION, COLLISION	IIC	2	FOLLOW ABS FOR EMERGENCY ELECTRICAL POWER. PROVIDE SYSTEM REDUNDANCY.	IIE	3	ABS, SECTIONS 7.25 & 7.27. REDUNDANCY: TBD.	TIME DEPENDENT
3.3.02A	EXPLOSION IN BATTERY COMPARTMENT	DAMAGE TO OR MALFUNCTION OF VENTILATION SYSTEM FOR BATTERY EMISSIONS DURING USAGE	FIRE, AIR CONTAMINATION	IIC	2	FOLLOW CFR AND ABS FOR BATTERY SYSTEM DESIGN. PROVIDE PROPER OPERATING PROCEDURES.	IID	2	46 CFR 111.15-10. ABS, SECTION 7.23. OP PROC: MTS III, SECTION B.2.	TIME DEPENDENT
3.3.02B	EXPLOSION IN BATTERY COMPARTMENT	DAMAGE OR MALFUNCTION OF VENTILATION SYSTEM OF LEAD ACID BATTERY HYDROGEN EMISSIONS DURING CHARGING	FIRE, AIR CONTAMINATION	IIC	2	FOLLOW CFR FOR POWER VENTILATION SYSTEM. PROVIDE PROPER OPERATING PROCEDURES.	IID	2	46 CFR 111.15-10. OP PROC: MTS III, SECTION B.2.	TIME DEPENDENT
3.3.03	BATTERY EMISSIONS SUCH AS STIBINE, HYDROGEN, OR ARSINE TO CABIN	DAMAGE TO BATTERY COMPARTMENT OR MALFUNCTION OF COMPONENT	AIR CONTAMINATION, FIRE	IIC	2	PROVIDE BATTERY EMISSIONS MONITORS. PROVIDE PROPER OPERATING PROCEDURES.	IID	2	USCG, MAY 87, P.2. OP PROC: MTS III, SECTION B.2.	TIME DEPENDENT

ELEMENT: SUBMERSIBLE
SYSTEM: SYSTEMS
SUBSYSTEM: ELECTRICAL

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
3.3.04A	LEAKAGE OF LEAD BATTERY ACID FROM BATTERY COMPARTMENT	DAMAGE TO BATTERY COMPARTMENT, MALFUNCTION OF COMPONENT, OR TOO GREAT TRIM ANGLE	INJURY DUE TO ACID	IIC	2	PROVIDE SEALED BATTERY COMPARTMENT. PROVIDE PROPER OPERATING PROCEDURES.	IID	2	COMPARTMENT: TBD. OP PROC: MTS III, SECTION B.2.	
3.3.04B	LEAKAGE OF LEAD BATTERY ACID FROM BATTERY COMPARTMENT	DAMAGE TO BATTERY COMPARTMENT, MALFUNCTION OF COMPONENT, OR TOO GREAT TRIM ANGLE	DAMAGE TO NON-METALLIC HULL MATERIALS	IIC	2	PROVIDE SEALED BATTERY COMPARTMENT. PROVIDE PROPER OPERATING PROCEDURES.	IID	2	COMPARTMENT: TBD. OP PROC: MTS III, SECTION B.2.	
3.3.05A	FORMATION OF TOXIC CHLORINE OR OTHER GASES IN CABIN	DAMAGE TO BATTERY COMPARTMENT PERMITS SEA WATER CONTAMINATION	AIR CONTAMINATION.	IIC	2	PROTECT BATTERIES FROM SALT WATER CONTAMINATION.	IIE	3	USCG, MAY 87, P.2.	TIME DEPENDENT
3.3.05B	FORMATION OF TOXIC GASES IN CABIN	EXCESSIVE HUMIDITY CAUSES CONDENSATION ON BATTERY	AIR CONTAMINATION.	IIB	1	FOLLOW ABS TO DESIGN FOR 100% HUMIDITY. PROVIDE PROPER HUMIDITY CONTROL.	IID	2	ABS, SECTION 7.9. HUMIDITY: TBD.	TIME DEPENDENT

ELEMENT: SUBMERSIBLE
SYSTEM: SYSTEMS
SUBSYSTEM: LIGHTING

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
3.4.01A	INADEQUATE VISIBILITY FOR PILOTING.	IMPROPER DESIGN OR SELECTION OF NAVIGATIONAL LIGHTS	COLLISION	IIC	2	FOLLOW INTERNATIONAL REGULATIONS FOR NAVIGATIONAL LIGHTS	IIE	3	MTS I, SECTION D.2.3 (SURFACED) AND D.3.3 (SUBMERGED). 33 CFR 81.	
3.4.01B	INADEQUATE VISIBILITY FOR PILOTING	IMPROPER FABRICATION OF NAVIGATIONAL LIGHTS	COLLISION	IC	1	FOLLOW ABS FOR ELECTRICAL INSTALLATION	IE	3	ABS, SECTION 7	
3.4.01C	LOSS OF VISIBILITY FOR PILOTING	IMPROPER OR LACK OF MAINTENANCE TO NAVIGATIONAL LIGHTS (SEE ALSO 6.4)	COLLISION	IC	1	PREVENTIVE MAINTENANCE PROGRAM.	IE	3	ABS, SECTION B.45, MTS I, SECTION H, MTS II, SECTION J.	
3.4.01D	LOSS OF VISIBILITY FOR PILOTING	IMPROPER OPERATION OF NAVIGATIONAL LIGHTS (SEE ALSO 6.1)	COLLISION	IC	1	PROVIDE PROPER OPERATING PROCEDURES. TRAINING PROGRAM.	ID	2	OP PROC: MTS III, SECTION B.2. TRAINING: MTS I, SECTION I.	
3.4.01E	LOSS OF VISIBILITY FOR PILOTING	LOSS OF ELECTRICAL POWER TO NAVIGATIONAL LIGHTS (SEE ALSO 3.3)	COLLISION	IC	1	PROVIDE EMERGENCY ELECTRICAL POWER TO NAVIGATIONAL LIGHTS. PROVIDE SYSTEM REDUNDANCY.	IE	3	ABS, SECTION 7.27, USCG, MAY 87, P.2.	
3.4.01F	LOSS OF VISIBILITY FOR PILOTING	ACCIDENT OR COLLISION DAMAGES NAVIGATIONAL LIGHTS	COLLISION	IC	1	PROVIDE PROPER OPERATING PROCEDURES (SEE SECTION 6.1.). PROVIDE SYSTEM REDUNDANCY.	ID	2	OP PROC: MTS III, SECTION B.2. MTS I, SECTION E.2.1	
3.4.02A	NO VISIBILITY FOR PILOTING OR FOR REPAIR OF EQUIPMENT	NO INTERIOR LIGHTS	INABILITY TO SURFACE, COLLISION, INJURY DUE TO FALL	IIC	2	FOLLOW CFR AND NAVY GUIDELINES FOR INTERIOR LIGHTING.	IIE	3	46 CFR 197.328. NAVMAT P-9290, SECTION B.8.	TIME DEPENDENT.

ELEMENT: SUBMERSIBLE
SYSTEM: SYSTEMS
SUBSYSTEM: LIGHTING

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HR12	HAZARD CONTROL REFERENCES	NOTES
3.4.02B	INADEQUATE VISIBILITY FOR PILOTING OR FOR REPAIR OF EQUIPMENT	IMPROPER DESIGN OR SELECTION OF INTERIOR LIGHTS	INABILITY TO SURFACE, COLLISION, INJURY DUE TO FALL	IIC	2	FOLLOW CFR AND NAVY FOR INTERIOR LIGHTING.	IIE	3	46 CFR 197.328. NAVMAT P-9250, SECTION B.6.	TIME DEPENDENT
3.4.02C	INADEQUATE VISIBILITY FOR PILOTING OR FOR REPAIR OF EQUIPMENT	IMPROPER FABRICATION OR INSTALLATION OF INTERIOR LIGHTS	INABILITY TO SURFACE, COLLISION, INJURY DUE TO FALL	IIC	2	FOLLOW CFR AND ABS FOR ELECTRICAL INSTALLATION. INSPECTION DURING MANUFACTURE.	IIE	3	46 CFR 183. ABS, SECTION 7. INSPECTION: 46 CFR 176.05, 176.10, ABS, SECTION C.17.	TIME DEPENDENT
3.4.02D	LOSS OF VISIBILITY FOR PILOTING OR FOR REPAIR OF EQUIPMENT	IMPROPER OR LACK OF MAINTENANCE TO INTERIOR LIGHTS (SEE ALSO 6.4)	INABILITY TO SURFACE, COLLISION, INJURY DUE TO FALL	IIC	2	PREVENTIVE MAINTENANCE PROGRAM.	IIE	3	ABS, SECTION B.45, MTS I, SECTION H, MTS II, SECTION J.	TIME DEPENDENT
3.4.02E	LOSS OF VISIBILITY FOR PILOTING OR FOR REPAIR OF EQUIPMENT	IMPROPER OPERATION OF INTERIOR LIGHTS (SEE ALSO 6.1)	INABILITY TO SURFACE, COLLISION, INJURY DUE TO FALL	IIC	2	PROVIDE PROPER OPERATING PROCEDURES. TRAINING PROGRAM.	IID	2	OP PROC: MTS III, SECTION B.2. TRAINING: MTS I, SECTION I.	TIME DEPENDENT
3.4.02F	LOSS OF VISIBILITY FOR PILOTING OR FOR REPAIR OF EQUIPMENT	LOSS OF ELECTRICAL POWER OR CONTROL TO INTERIOR LIGHTS (SEE ALSO 3.3)	INABILITY TO SURFACE, COLLISION, INJURY DUE TO FALL	IIC	2	FOLLOW CFR, MTS, AND ABS TO PROVIDE EMERGENCY POWER TO EMERGENCY LIGHTS. PROVIDE SYSTEM REDUNDANCY.	IIE	3	46 CFR 184.30. MTS III, SECTION B.4. ABS, SECTION 7.25. USCG, MAY 87, P.2.	TIME DEPENDENT

ELEMENT: SUBMERSIBLE
SYSTEM: SYSTEMS
SUBSYSTEM: LIGHTING

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
3.4.02G	LOSS OF VISIBILITY FOR PILOTING OR FOR REPAIR OF EQUIPMENT	ACCIDENT OR COLLISION DAMAGES INTERIOR LIGHTS	INABILITY TO SURFACE, COLLISION, INJURY DUE TO FALL	IID	2	PROVIDE PROPER OPERATING PROCEDURES (SEE SECTION 6.1.). FOLLOW CFR AND ABS TO PROVIDE EMERGENCY POWER TO EMERGENCY LIGHTS.	IIE	3	OP PROC: MTS III, SECTION B.2. 46 CFR 184.30. ABS, SECTION 7.25	TIME DEPENDENT
3.4.02H	LOSS OF VISIBILITY FOR PILOTING OR FOR REPAIR OF EQUIPMENT	MALFUNCTION OF INTERIOR LIGHTS	INABILITY TO SURFACE, COLLISION, INJURY DUE TO FALL	IIC	2	FOLLOW CFR AND ABS TO PROVIDE EMERGENCY POWER TO EMERGENCY LIGHTS. PROVIDE SYSTEM REDUNDANCY.	IIE	3	46 CFR 184.30. ABS, SECTION 7.25. REDUNDANCY: TBD.	TIME DEPENDENT

ELEMENT: SUBMERSIBLE
SYSTEM: SYSTEMS
SUBSYSTEM: COMMUNICATION

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
3.5.01A	LACK OF UNDERWATER COMMUNICATIONS WITH SURFACE SUPPORT VESSEL	NO UNDERWATER COMMUNICATION SYSTEM PROVIDED ON SUBMERSIBLE	COLLISION	IID	2	FOLLOW CFR, ABS, AND MTS FOR UNDERWATER COMMUNICATIONS, TO ENSURE SYSTEM IS ON SUB.	IIE	3	46 CFR 197.328, ABS, SECTION 2.5. MTS I, SECTION D.3.1.	
3.5.01B	INADEQUATE UNDERWATER COMMUNICATIONS WITH SURFACE SUPPORT VESSEL	IMPROPER DESIGN OR SELECTION OF UNDERWATER COMMUNICATION SYSTEM	COLLISION	IIC	2	FOLLOW CFR, NAVY, ABS, AND MTS FOR UNDERWATER COMMUNICATIONS SYSTEM.	IIE	3	46 CFR 197.328. NAVMAT P-9290, 8.4.4J. ABS, SECTION 2.5. MTS I, SECTION G.3.1. MTS III, SECTION C.1.2.	
3.5.01C	INADEQUATE UNDERWATER COMMUNICATIONS WITH SURFACE SUPPORT VESSEL	IMPROPER FABRICATION OR INSTALLATION OF UNDERWATER COMMUNICATION SYSTEM	COLLISION	IIC	2	INSPECTION OF INSTALLATION.	IIE	3	46 CFR 176.05, 176.10, ABS, SECTION C.17.	
3.5.01D	LOSS OF UNDERWATER COMMUNICATIONS WITH SURFACE SUPPORT VESSEL	IMPROPER OR LACK OF MAINTENANCE TO UNDERWATER COMMUNICATION SYSTEM (SEE ALSO 6.4)	COLLISION	IIC	2	PREVENTIVE MAINTENANCE PROGRAM TO INCLUDE TESTING OF COMMUNICATIONS PRIOR TO EACH DIVE.	IIE	3	ABS, SECTION B.45, MTS I, SECTION H, MTS II, SECTION J.	
3.5.01E	LOSS OF UNDERWATER COMMUNICATIONS WITH SURFACE SUPPORT VESSEL	IMPROPER OPERATION OF UNDERWATER COMMUNICATION SYSTEM (SEE ALSO 6.1)	COLLISION	IID	2	PROVIDE PROPER OPERATING PROCEDURES. TRAINING PROGRAM.	IID	2	OP PROC: MTS III, SECTION B.2.4. TRAINING: MTS I, SECTION I.	

ELEMENT: SUBMERSIBLE
SYSTEM: SYSTEMS
SUBSYSTEM: COMMUNICATION

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
3.5.01F	LOSS OF UNDERWATER COMMUNICATIONS WITH SURFACE SUPPORT VESSEL	LOSS OF ELECTRICAL POWER TO UNDERWATER COMMUNICATION SYSTEM (SEE ALSO 3.3)	COLLISION	IIC	2	FOLLOW MTS TO PROVIDE POWER FROM EMERGENCY BATTERY TO UNDERWATER COMMUNICATIONS. PROVIDE SYSTEM REDUNDANCY.	IIE	3	MTS I, SECTION G.3.1. REDUNDANCY: TBD.	
3.5.01G	LOSS OF UNDERWATER COMMUNICATIONS WITH SURFACE SUPPORT VESSEL	COLLISION OR ACCIDENT DAMAGES UNDERWATER COMMUNICATION SYSTEM	COLLISION	IIC	2	PROVIDE PROPER OPERATING PROCEDURES (SEE SECTION 6.1.). PROVIDE SYSTEM REDUNDANCY.	IIE	3	OP PROC: MTS III, SECTION B.2.4. REDUNDANCY: TBD.	
3.5.01H	LOSS OF UNDERWATER COMMUNICATIONS WITH SURFACE SUPPORT VESSEL	MALFUNCTION OF UNDERWATER COMMUNICATION SYSTEM	COLLISION	IIC	2	PROVIDE SYSTEM REDUNDANCY.	IIE	3	MTS III, SECTION C.1.2.	
3.5.01I	LOSS OF UNDERWATER COMMUNICATIONS WITH SURFACE SUPPORT VESSEL.	LOSS OF COMMUNICATIONS DURING DIVE BECAUSE TOP AND BOTTOM TRANSDUCERS NOT PROVIDED.	COLLISION	IIC	2	PROVIDE TOP AND BOTTOM TRANSDUCERS FOR CONTINUOUS AND EFFECTIVE COMMUNICATIONS.	IIE	3	MTS III, SECTION B.2.4.	
3.5.02A	LOSS OF SURFACE COMMUNICATIONS WITH SURFACE VESSELS	IMPROPER DESIGN OR SELECTION OF SURFACE COMMUNICATION SYSTEM	COLLISION	IIC	2	FOLLOW CFR AND MTS FOR SURFACE COMMUNICATIONS.	IIE	3	46 CFR 184.25. MTS I, SECTION G.3.2.	

ELEMENT: SUBMERSIBLE
SYSTEM: SYSTEMS
SUBSYSTEM: COMMUNICATION

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
3.5.02B	LOSS OF SURFACE COMMUNICATIONS WITH SURFACE VESSELS	IMPROPER FABRICATION OR INSTALLATION OF SURFACE COMMUNICATION SYSTEM	COLLISION	IIC	2	FOLLOW CFR AND MTS FOR SURFACE COMMUNICATIONS. INSPECTION DURING MANUFACTURE.	IIE	3	46 CFR 184.25. MTS II, SECTION G.3.2. INSPECTION: 46 CFR 176.05, 176.10, ABS, SECTION C.17.	
3.5.02C	LOSS OF SURFACE COMMUNICATIONS WITH SURFACE VESSELS	IMPROPER OR LACK OF MAINTENANCE TO SURFACE COMMUNICATION SYSTEM (SEE ALSO 6.4)	COLLISION	IIC	2	REQUIRE TESTING OF COMMUNICATION SYSTEM PRIOR TO EACH DIVE. PREVENTIVE MAINTENANCE PROGRAM.	IIE	3	TESTING: MTS III, SECTION B.2.4. MAINTENANCE: ABS, SECTION B.45, MTS I, SECTION H, MTS II, SECTION J.	
3.5.02D	LOSS OF SURFACE COMMUNICATIONS WITH SURFACE VESSELS	IMPROPER OPERATION OF SURFACE COMMUNICATION SYSTEM (SEE ALSO 6.1)	COLLISION	IIC	2	PROVIDE PROPER OPERATING PROCEDURES. TRAINING PROGRAM.	IID	2	OP PROC: MTS III, SECTION B.2.4. TRAINING: MTS I, SECTION I.	
3.5.02E	LOSS OF SURFACE COMMUNICATIONS WITH SURFACE VESSELS	LOSS OF ELECTRICAL POWER TO SURFACE COMMUNICATION SYSTEM (SEE ALSO 3.3)	COLLISION	IIC	2	FOLLOW MTS TO PROVIDE EMERGENCY POWER TO SURFACE COMMUNICATION SYSTEM. PROVIDE SYSTEM REDUNDANCY.	IIE	3	MTS I, SECTION G.3.2. REDUNDANCY: TBD.	
3.5.02F	LOSS OF SURFACE COMMUNICATIONS WITH SURFACE VESSELS	COLLISION OR ACCIDENT DAMAGES SURFACE COMMUNICATION SYSTEM	COLLISION	IIC	2	PROVIDE PROPER OPERATING PROCEDURES (SEE SECTION 6.1.). PROVIDE SYSTEM REDUNDANCY.	IIE	3	OP PROC: MTS III, SECTION B.2. REDUNDANCY: TBD.	

ELEMENT: SUBMERSIBLE
SYSTEM: SYSTEMS
SUBSYSTEM: COMMUNICATION

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
3.5.02G	LOSS OF SURFACE COMMUNICATIONS WITH SURFACE VESSELS	EXCESSIVE INTERFERENCE BY RADIOS IN VICINITY OF SUB	COLLISION	IIC	2	PROVIDE ALTERNATE MEANS OF COMMUNICATION.	IIE	3	MTS III, SECTION B.2.4.	
3.5.02H	LOSS OF SURFACE COMMUNICATIONS WITH SURFACE VESSELS	NO MEANS OF SURFACE COMMUNICATIONS INSTALLED ON SUBMERSIBLE	COLLISION	IIC	2	FOLLOW CFR AND ABS FOR SURFACE COMMUNICATIONS TO ENSURE SYSTEM IS INCLUDED ON SUB.	IIE	3	46 CFR 184.25, ABS, SECTION 2.5.	
3.5.02I	LOSS OF SURFACE COMMUNICATIONS WITH SURFACE VESSELS	MALFUNCTION OF SURFACE COMMUNICATIONS SYSTEM	COLLISION	IIC	2	PROVIDE SYSTEM REDUNDANCY.	IIE	3	MTS III, SECTION C.1.2.	

ELEMENT: SUBMERSIBLE
SYSTEM: SYSTEMS
SUBSYSTEM: LIFE SUPPORT

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
3.6.01A	LOSS OF OXYGEN SUPPLY TO CABIN	IMPROPER DESIGN, SELECTION, OR SIZING OF OXYGEN SYSTEM	AIR CONTAMINATION	IIC	2	FOLLOW CFR, ABS, AND NAVY FOR OXYGEN SYSTEMS. USCG PLAN REVIEW.	IIE	3	46 CFR 197.328 "BELOW 25%". ABS, SECTION 5.5 "BELOW 25%". NAVMAT P-9290, SECTION B.4.4.A "BELOW 21 %". MTS I, SECTION C.2. USCG, MAY 87, P.3.	TIME DEPENDENT.
3.6.01B	LOSS OF OXYGEN SUPPLY TO CABIN	IMPROPER FABRICATION OR INSTALLATION OF OXYGEN SYSTEM	AIR CONTAMINATION	IIC	2	FOLLOW ABS, NAVY, AND MTS FOR OXYGEN SYSTEMS. INSPECTION DURING MANUFACTURE.	IIE	3	ABS, SECTION 5.5. NAVMAT P-9290, B.4.4.A. MTS I, SECTION C.2. INSPECTION: 46 CFR 176.05, 176.10, ABS, SECTION C.17.	TIME DEPENDENT.
3.6.01C	LOSS OF OXYGEN SUPPLY TO CABIN	IMPROPER OR LACK OF MAINTENANCE TO OXYGEN SYSTEM (SEE ALSO 6.4)	AIR CONTAMINATION	IIC	2	PREVENTIVE MAINTENANCE PROGRAM.	IIE	3	ABS, SECTION B.45, MTS I, SECTION H, MTS II, SECTION J.	TIME DEPENDENT.
3.6.01D	LOSS OF OXYGEN SUPPLY TO CABIN	IMPROPER OPERATION OF OXYGEN SYSTEM (SEE ALSO 6.1)	AIR CONTAMINATION	IIC	2	PROVIDE PROPER OPERATING PROCEDURES. TRAINING PROGRAM.	IID	2	OP PROC: MTS III, SECTION B.2. TRAINING: MTS I, SECTION I.	TIME DEPENDENT.
3.6.01E	LOSS OF OXYGEN SUPPLY TO CABIN	LOSS OF PNEUMATIC POWER OR CONTROL TO OXYGEN SYSTEM (SEE ALSO 3.1)	AIR CONTAMINATION	IIC	2	PROVIDE MANUAL CONTROL.	IIE	3	MTS I, SECTION C.2.4.	TIME DEPENDENT.

ELEMENT: SUBMERSIBLE
SYSTEM: SYSTEMS
SUBSYSTEM: LIFE SUPPORT

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
3.6.01F	LOSS OF OXYGEN SUPPLY TO CABIN	LOSS OF HYDRAULIC POWER OR CONTROL TO OXYGEN SYSTEM (SEE ALSO 3.2)	AIR CONTAMINATION	IIC	2	PROVIDE MANUAL CONTROL.	IIE	3	MTS I, SECTION C.2.4.	TIME DEPENDENT
3.6.01G	LOSS OF OXYGEN SUPPLY TO CABIN	LOSS OF ELECTRICAL POWER OR CONTROL TO OXYGEN SYSTEM (SEE ALSO 3.3)	AIR CONTAMINATION	IIC	2	PROVIDE MANUAL CONTROL, BACK UP MONITORS OR POWER SOURCE.	IIE	3	MTS I, SECTIONS C.2.4 AND G.2.4.	TIME DEPENDENT
3.6.01H	LOSS OF OXYGEN SUPPLY TO CABIN	INACCURATE READINGS FROM QUANTITY INDICATORS OR MONITORS FOR OXYGEN SYSTEM	AIR CONTAMINATION	IIC	2	ESTABLISH CALIBRATION PROGRAM. BACK-UP UNIT, BACK-UP POWER SOURCE. PREVENTIVE MAINTENANCE PROGRAM.	IID	2	MTS I, SECTIONS C.7.1, C.7.7 THROUGH C.7.9. MAINTENANCE: ABS SECTION B.45, MTS I, SECTION H, MTS II, SECTION J.	TIME DEPENDENT
3.6.01I	LOSS OF OXYGEN SUPPLY TO CABIN	FAILURE OF OXYGEN STORAGE CYLINDERS (SEE ALSO 1.3.03)	AIR CONTAMINATION	IID	2	FOLLOW CFR TO USE DOT APPROVED CYLINDERS. PROVIDE SYSTEM REDUNDANCY, SUCH AS REQUIRING OXYGEN CYLINDERS TO MEET CODES AND CARRY THEM EXTERNALLY, SEPARATE FROM PASSENGERS.	IIE	3	46 CFR 147.04 AND 147.05. REDUNDANCY: TBD.	TIME DEPENDENT

ELEMENT: SUBMERSIBLE
SYSTEM: SYSTEMS
SUBSYSTEM: LIFE SUPPORT

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
3.6.01J	LOSS OF OXYGEN SUPPLY TO CABIN	FAILURE OF OXYGEN REGULATING VALVE	AIR CONTAMINATION	IIC	2	PROVIDE SYSTEM REDUNDANCY, SUCH AS REDUNDANT FLOW CONTROL VALVE, MANUAL BYPASS TO PRESSURE REGULATOR, A BACK-UP REGULATOR, AND FLOWMETERS BETWEEN OXYGEN BANKS AND CABIN.	IIE	3	MTS I, SECTION C.2.4.	TIME DEPENDENT
3.6.01K	LOSS OF OXYGEN SUPPLY TO CABIN	IMPURITY OF INDUSTRIAL QUALITY OXYGEN	AIR CONTAMINATION	IIB	1	FOLLOW NAVY FOR BREATHING GAS REQUIREMENTS. USE MEDICAL QUALITY OXYGEN.	IIE	3	NAVMAT P-9290, APPENDIX E. MEDICAL QUALITY OXYGEN: TBD.	TIME DEPENDENT
3.6.01L	LOSS OF OXYGEN SUPPLY TO CABIN	OXYGEN SYSTEM CHARGED WITH ANOTHER GAS	AIR CONTAMINATION	IIC	2	STRICT CONTROL OVER MAINTENANCE OPERATIONS. TESTING OXYGEN SYSTEMS/LEVELS PRIOR TO EACH DIVE.	IIE	3	MTS I, SECTION J.5.0. MAINTENANCE: MTS I, SECTION H, MTS II, SECTION J, ABS, SECTION B.45.	TIME DEPENDENT
3.6.01M	EXPLOSION OF PRESSURE VESSEL FOR OXYGEN	OVERPRESSURIZATION DURING RECHARGING PROCESS	EXPLOSION, FIRE, INJURY	IC	1	PROVIDE MECHANICAL CONTROLS TO PREVENT OVERCHARGING. PROVIDE STRICT CONTROL OVER MAINTENANCE PROCEDURES.	IE	3	TBD	

ELEMENT: SUBMERSIBLE
SYSTEM: SYSTEMS
SUBSYSTEM: LIFE SUPPORT

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
3.6.02	IGNITION SOURCE REACHES AND INVOLVES OXYGEN STORAGE SYSTEM	OXYGEN STORAGE CYLINDERS LOCATED IN UNPROTECTED MANNER ON BOARD SUB	FIRE, EXPLOSION	ID	2	STORE OXYGEN CYLINDERS OUTSIDE PRESSURE HULL, PROTECTED	IE	3	MTS I, SECTIONS C.2.2 AND E.2.	
3.6.03A	LOSS OF TEMPERATURE AND HUMIDITY CONTROL OR AIR CIRCULATION WITHIN CABIN	IMPROPER DESIGN OR SIZING OF AIR CONDITIONING SYSTEM	AIR CONTAMINATION, ILLNESS	IIC	2	FOLLOW INDUSTRY HVAC STANDARDS FOR AIR CONDITIONING DESIGN. HVAC DESIGN APPROVAL.	IIE	3	MTS I, SECTION C.6. 46 CFR 58.20, 159.	TIME DEPENDENT
3.6.03B	LOSS OF TEMPERATURE AND HUMIDITY CONTROL OR AIR CIRCULATION WITHIN CABIN	IMPROPER FABRICATION OR INSTALLATION OF AIR CONDITIONING SYSTEM	AIR CONTAMINATION, ILLNESS	IIC	2	INSPECT DURING INSTALLATION. ACCEPTANCE TESTING.	IIE	3	MTS I, SECTION C.6. 46 CFR 58.20, 176.05, 176.10. ABS, SECTION C.17.	TIME DEPENDENT
3.6.03C	LOSS OF TEMPERATURE AND HUMIDITY CONTROL OR AIR CIRCULATION WITHIN CABIN	IMPROPER OR LACK OF MAINTENANCE TO AIR CONDITIONING SYSTEM (SEE ALSO 6.4)	AIR CONTAMINATION, ILLNESS	IIC	2	PREVENTIVE MAINTENANCE PROGRAM.	IIE	3	MTS I, SECTIONS C.6.6, G.6.7, AND H. MTS II, SECTION J. ABS, SECTION B.45.	TIME DEPENDENT
3.6.03D	LOSS OF TEMPERATURE AND HUMIDITY CONTROL OR AIR CIRCULATION WITHIN CABIN	IMPROPER OPERATION OF AIR CONDITIONING SYSTEM (SEE ALSO 6.1)	AIR CONTAMINATION, ILLNESS	IIC	2	PROVIDE PROPER OPERATING PROCEDURES. TRAINING PROGRAM.	IID	2	OP PROC: MTS III, SECTION B.2. TRAINING: MTS I, SECTION I.	TIME DEPENDENT
3.6.03E	LOSS OF TEMPERATURE AND HUMIDITY CONTROL OR AIR CIRCULATION WITHIN CABIN	LOSS OF PNEUMATIC CONTROL TO AIR CONDITIONING SYSTEM (SEE ALSO 3.1)	AIR CONTAMINATION, ILLNESS	IIC	2	PROVIDE MANUAL CONTROL.	IIE	3	MTS I, SECTION C.6.5.	TIME DEPENDENT

ELEMENT: SUBMERSIBLE
SYSTEM: SYSTEMS
SUBSYSTEM: LIFE SUPPORT

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
3.6.03F	LOSS OF TEMPERATURE AND HUMIDITY CONTROL OR AIR CIRCULATION WITHIN CABIN	LOSS OF HYDRAULIC CONTROL TO AIR CONDITIONING SYSTEM (SEE ALSO 3.2)	AIR CONTAMINATION, ILLNESS	IIC	2	PROVIDE MANUAL CONTROL.	IIE	3	MTS I, SECTION C.6.5.	TIME DEPENDENT
3.6.03G	LOSS OF TEMPERATURE AND HUMIDITY CONTROL OR AIR CIRCULATION WITHIN CABIN	LOSS OF ELECTRIC POWER OR CONTROL TO AIR CONDITIONING SYSTEM (SEE ALSO 3.3)	AIR CONTAMINATION, ILLNESS	IIC	2	PROVIDE SYSTEM REDUNDANCY. PROVIDE EMERGENCY POWER TO AIR CONDITIONING SYSTEM.	IIE	3	EMER POWER: ABS, SECTION 7.27. MTS I, SECTION C.6.5.	TIME DEPENDENT
3.6.03H	LOSS OF *TEMPERATURE AND* HUMIDITY CONTROL OR AIR CIRCULATION WITHIN CABIN.	DAMAGE TO AIR *CONDITIONING* SYSTEM COMPONENT	AIR *CONTAMINATION*, ILLNESS.	IIB	1	PROVIDE INDICATORS THAT SHOW IF SYSTEM IS OPERATING, PRESSURE, TEMPERATURE AND HUMIDITY. PROVIDE MANUAL CONTROL.	IID	2	MTS I, SECTIONS C.6.5 AND C.7.3 THROUGH C.7.5.	TIME DEPENDENT
3.6.04	REFRIGERANT LEAK WITHIN PRESSURE *HULL*	DAMAGE TO AIR CONDITIONING SYSTEM COMPONENT	AIR CONTAMINATION	IIB	1	PROVIDE PROPER OPERATING *PROCEDURES (SEE* SECTION 6.1.). PROVIDE SAFE EQUIPMENT LOCATION. REQUIRE ADDITION OF SENSORS. CHOOSE LESS *TOXIC* REFRIGERANT.	IID	2	OP PROC: MTS III, SECTION B.2. EQUIPMENT: TBD. REFRIGERANT: TBD.	TIME DEPENDENT

ELEMENT: SUBMERSIBLE
SYSTEM: SYSTEMS
SUBSYSTEM: LIFE SUPPORT

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
3.6.05	OIL LEAK WITHIN PRESSURE HULL	DAMAGE TO AIR CONDITIONING SYSTEM COMPONENT	AIR CONTAMINATION, INJURY DUE TO FALL	IID	2	PROVIDE PROPER OPERATING PROCEDURES (SEE SECTION 6.1.). PROVIDE SAFE EQUIPMENT LOCATION.	IIE	3	OP PROC: MTS III, SECTION B.2. EQUIPMENT: TBD.	TIME DEPENDENT
3.6.06	UNDER-PRESSURIZATION OF HULL PREVENTS OPENING OF HATCH ON SURFACE	INSUFFICIENT RATE OF OXYGEN FLOW TO CABIN OR LOWER THAN NORMAL TEMPERATURE IN CABIN DUE TO MALFUNCTION OF AIR CONDITIONING SYSTEM	UNABLE TO EVACUATE SUB	IIC	1	FOLLOW CFR, ABS, AND ASME TO PROVIDE PRESSURE EQUALIZATION MECHANISM. PROVIDE SYSTEM REDUNDANCY.	IIE	3	46 CFR 197.328. ABS, SECTION 5.13. ASME PVHO-1A, SECTION 1.6. REDUNDANCY: TBD.	
3.6.07	OVER-PRESSURIZATION OF PRESSURE HULL	EMERGENCY ASCENT, EXCESSIVE RATE OF OXYGEN FLOW TO CABIN, EXCESSIVE AMOUNT OF CO2 IN CABIN, HIGHER THAN NORMAL TEMPERATURE IN CABIN DUE TO MALFUNCTION OF AIR CONDITIONING SYSTEM, AND AIR LEAK TO CABIN	INJURY	IIC	2	FOLLOW CFR, ABS, AND ASME TO PROVIDE PRESSURE EQUALIZATION MECHANISM. PROVIDE PROPER OPERATING PROCEDURES.	IIE	3	46 CFR 197.328. ABS, SECTION 5.13. ASME PVHO-1A, SECTION 1.6. OP PROC: MTS III, SECTION B.2.	
3.6.08A	EXCESSIVE AMOUNTS OF CO2 IN CABIN	NO CO2 REMOVAL SYSTEM INSTALLED AND UNABLE TO SURFACE	AIR CONTAMINATION, DEATH	IIC	2	FOLLOW CFR, ABS, AND NAVY GUIDELINES FOR CO2 REMOVAL SYSTEMS	IIE	3	46 CFR 197.328. ABS, SECTION 5.7. NAVMAT P-9290, SECTION B.4.4.B.	TIME DEPENDENT

ELEMENT: SUBMERSIBLE
SYSTEM: SYSTEMS
SUBSYSTEM: LIFE SUPPORT

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
3.6.08B	EXCESSIVE AMOUNT OF CO2 IN CABIN	IMPROPER DESIGN OR SIZING OF CO2 REMOVAL SYSTEM	AIR CONTAMINATION, DEATH	IIC	2	FOLLOW CFR, ABS, AND NAVY FOR CO2 REMOVAL SYSTEMS.	IIE	3	46 CFR 197.328 "BELOW 2%". ABS, SECTION 5.7 "BELOW 1.0%". NAVMAT P-9290, SECTION B.4.4.B "BELOW 1.0%". MTS I, SECTION C.3.	TIME DEPENDENT
3.6.08C	EXCESSIVE AMOUNT OF CO2 IN CABIN	IMPROPER FABRICATION OR INSTALLATION OF CO2 REMOVAL SYSTEM	AIR CONTAMINATION, DEATH	IIC	2	FOLLOW CFR, ABS, AND NAVY FOR CO2 REMOVAL SYSTEMS. INSPECTION DURING MANUFACTURE.	IIE	3	46 CFR 197.328. ABS, SECTION 5.7. NAVMAT P-9290, SECTION B.4.4.B. MTS I, SECTION C.3. INSPECTION: 46 CFR 176.05, 176.10, ABS, SECTION C.17.	TIME DEPENDENT
3.6.08D	EXCESSIVE AMOUNT OF CO2 IN CABIN	IMPROPER OR LACK OF MAINTENANCE TO CO2 REMOVAL SYSTEM (SEE ALSO 6.4)	AIR CONTAMINATION, DEATH	IIC	2	PREVENTIVE MAINTENANCE PROGRAM	IIE	3	MTS I, SECTIONS C.3 AND H, MTS II, SECTION J, ABS, SECTION B.45.	TIME DEPENDENT
3.6.08E	EXCESSIVE AMOUNT OF CO2 IN CABIN	IMPROPER OPERATION OF CO2 REMOVAL SYSTEM (SEE ALSO 6.1)	AIR CONTAMINATION, DEATH	IIC	2	PROVIDE PROPER OPERATING PROCEDURES TO INCLUDE ADHERANCE TO MANUFACTURER'S OPERATIONAL PROCEDURES. TRAINING PROGRAM.	IID	2	OP PROC: MTS I, SECTION C.3, MTS III, SECTION B.2. TRAINING: MTS I, SECTION I.	TIME DEPENDENT

ELEMENT: SUBMERSIBLE
SYSTEM: SYSTEMS
SUBSYSTEM: LIFE SUPPORT

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
3.6.08F	EXCESSIVE AMOUNT OF CO2 IN CABIN	LOSS OF PNEUMATIC CONTROL TO CO2 REMOVAL SYSTEM (SEE ALSO 3.1)	AIR CONTAMINATION.	IIC	2	PROVIDE BACK-UP CONTROL.	IIE	3	MTS I, SECTION C.3.2.	TIME DEPENDENT
3.6.08G	EXCESSIVE AMOUNT OF CO2 IN CABIN	LOSS OF HYDRAULIC CONTROL TO CO2 REMOVAL SYSTEM (SEE ALSO 3.2)	AIR CONTAMINATION, DEATH	IIC	2	PROVIDE BACK-UP CONTROL.	IIE	3	MTS I, SECTION C.3.2.	TIME DEPENDENT
3.6.08H	EXCESSIVE AMOUNT OF CO2 IN CABIN	LOSS OF ELECTRICAL POWER AND CONTROL TO CO2 REMOVAL SYSTEM (SEE ALSO 3.3)	AIR CONTAMINATION, DEATH	IIC	2	PROVIDE EMERGENCY POWER TO CO2 SCRUBBER SYSTEM AND MONITORS.	IIE	3	ABS, SECTION 5.7. MTS I, SECTIONS 3.2 AND G.2.4.	TIME DEPENDENT
3.6.08I	EXCESSIVE AMOUNT OF CO2 IN CABIN	FAILURE OF CO2 REMOVAL FAN	AIR CONTAMINATION, DEATH	IIC	2	PROVIDE SYSTEM REDUNDANCY/ BACK-UP.	IIE	3	MTS I, SECTIONS C.3.2 AND G.2.4.	TIME DEPENDENT
3.6.08J	EXCESSIVE AMOUNT OF CO2 IN CABIN	INACCURATE READINGS FROM QUANTITY INDICATORS OR MONITORS FOR CO2 REMOVAL SYSTEM	AIR CONTAMINATION, DEATH	IIC	2	ESTABLISH CALIBRATION PROGRAM. PROVIDE BACK-UP CO2 INDICATOR.	IID	2	MTS I, SECTIONS C.3.5 AND G.2.4.	TIME DEPENDENT
3.6.08K	EXCESSIVE AMOUNT OF CO2 IN CABIN	MALFUNCTION OF CO2 REMOVAL SYSTEM	AIR CONTAMINATION, DEATH	IIC	2	PROVIDE SYSTEM REDUNDANCY/ BACK-UP.	IIE	3	MTS I, SECTION C.3.2.	TIME DEPENDENT
3.6.08L	EXCESSIVE AMOUONT OF CO2 IN CABIN	INSUFFICIENT SUPPLY OF CO2 ABSORBANT	AIR CONTAMINATION, DEATH	IIC	1	PROVIDE A BACK-UP SUPPLY OF CO2 ABSORBANT AS PART OF EMERGENCY SUPPLIES.	IIE	3	MTS I, SECTION C.3	

ELEMENT: SUBMERSIBLE
SYSTEM: SYSTEMS
SUBSYSTEM: LIFE SUPPORT

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
3.6.09A	LACK OF MEANS TO DETECT TOXIC OR FLAMMABLE GAS WITHIN CABIN	IMPROPER DESIGN OR SELECTION OF GAS DETECTOR	AIR CONTAMINATION.	IIC	2	FOLLOW ABS TO PROVIDE MEANS TO MONITOR CABIN ATMOSPHERE. USCG PLAN REVIEW.	IIE	3	ABS, SECTION 5.17. MTS I, SECTION C.7. USCG, MAY 87, P.3.	TIME DEPENDENT
3.6.09B	LACK OF MEANS TO DETECT TOXIC OR FLAMMABLE GAS WITHIN CABIN	IMPROPER FABRICATION OR INSTALLATION OF GAS DETECTOR	AIR CONTAMINATION.	IIC	2	FOLLOW MANUFACTURERS RECOMMENDATIONS FOR INSTALLATION. INSPECTION DURING MANUFACTURE.	IIE	3	MTS I, SECTION C.7. INSPECTION: 46 CFR 176.05, 176.10, ABS, SECTION C.17.	TIME DEPENDENT
3.6.09C	LACK OF MEANS TO DETECT TOXIC OR FLAMMABLE GAS WITHIN CABIN	IMPROPER OR LACK OF MAINTENANCE TO GAS DETECTOR (SEE ALSO 6.4)	AIR CONTAMINATION.	IIC	2	PREVENTIVE MAINTENANCE PROGRAM TO INCLUDE MANUFACTURER'S FOR MAINTENANCE.	IIE	3	MTS I, SECTIONS C.7 AND H, MTS II, SECTION J, ABS, SECTION B.45.	TIME DEPENDENT
3.6.09D	LACK OF MEANS TO DETECT TOXIC OR FLAMMABLE GAS WITHIN CABIN	IMPROPER OPERATION OF GAS DETECTOR (SEE ALSO 6.1)	AIR CONTAMINATION.	IIC	2	PROVIDE PROPER OPERATING PROCEDURES TO INCLUDE MANUFACTURER'S FOR OPERATION. TRAINING PROGRAM.	IID	2	MTS I, SECTION C.7, MTS III, SECTION B.2.	TIME DEPENDENT
3.6.09E	LACK OF MEANS TO DETECT TOXIC OR FLAMMABLE GAS WITHIN CABIN	LOSS OF ELECTRICAL POWER TO GAS DETECTOR (SEE ALSO 3.3)	AIR CONTAMINATION.	IIC	2	PROVIDE POWER FROM EMERGENCY BATTERY TO GAS DETECTORS. PROVIDE SYSTEM REDUNDANCY.	IIE	3	MTS I, SECTION C.7.0. REDUNDANCY: TBD.	TIME DEPENDENT
3.6.09F	LACK OF MEANS TO DETECT TOXIC OR FLAMMABLE GAS WITHIN CABIN	MALFUNCTION OF GAS DETECTOR	AIR CONTAMINATION.	IIC	2	PROVIDE SYSTEM REDUNDANCY.	IIE	3	MTS I, SECTION C.7.0.	TIME DEPENDENT

ELEMENT: SUBMERSIBLE
SYSTEM: SYSTEMS
SUBSYSTEM: EMERGENCY

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
3.7.01A	INABILITY TO CONTROL FIRE	NO MEANS OF FIRE PROTECTION ON BOARD SUB	AIR CONTAMINATION, INJURY, DEATH	IIC	2	FOLLOW CFR TO PROVIDE MEANS OF EXTINGUISHING FIRE IN THE INTERIOR.	IIE	3	46 CFR 197.328	TIME DEPENDENT.
3.7.01B	INABILITY TO CONTROL FIRE	IMPROPER DESIGN, SIZING, OR SELECTION OF FIRE EXTINGUISHING SYSTEM	AIR CONTAMINATION, INJURY, DEATH	IIC	2	FOLLOW ABS, NAVY, CFR, AND MTS FOR DESIGN AND SELECTION OF FIRE EXTINGUISHING SYSTEM.	IIE	3	ABS, SECTION 2.3. NAVMAT P-9290, B.4.4.1. 46 CFR 159. MTS I, SECTION G.5.0.	TIME DEPENDENT
3.7.01C	INABILITY TO CONTROL FIRE	IMPROPER FABRICATION OR INSTALLATION OF FIRE EXTINGUISHING SYSTEM	AIR CONTAMINATION, INJURY, DEATH	IIC	2	FOLLOW ABS, NAVY, AND MTS FOR DESIGN AND SELECTION OF FIRE EXTINGUISHING SYSTEM.	IIE	3	ABS, SECTION 2.3. NAVMAT P-9290, B.4.4.1. MTS I, SECTION G.5.0.	TIME DEPENDENT
3.7.01D	INABILITY TO CONTROL FIRE	IMPROPER OR LACK OF MAINTENANCE TO FIRE EXTINGUISHING SYSTEM (SEE ALSO 6.4)	AIR CONTAMINATION, INJURY, DEATH	IIC	2	PREVENTIVE MAINTENANCE PROGRAM.	IIE	3	MTS I, SECTIONS G.5.0 AND H, MTS II, SECTION J, ABS, SECTION B.45.	TIME DEPENDENT
3.7.01E	INABILITY TO CONTROL FIRE	IMPROPER OPERATION OF FIRE EXTINGUISHING SYSTEM (SEE ALSO 6.1)	AIR CONTAMINATION, INJURY, DEATH	IIC	2	EMERGENCY PROCEDURES. TRAINING PROGRAM.	IID	2	EMER PROC: MTS III, SECTION B.4.6.1. TRAINING: MTS I, SECTION I.	TIME DEPENDENT
3.7.01F	INABILITY TO CONTROL FIRE	MALFUNCTION OF FIRE EXTINGUISHING SYSTEM	AIR CONTAMINATION, INJURY, DEATH	IC	2	PROVIDE SYSTEM REDUNDANCY.	IE	3	TBD	TIME DEPENDENT

ELEMENT: SUBMERSIBLE
SYSTEM: SYSTEMS
SUBSYSTEM: EMERGENCY

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
3.7.02A	INABILITY TO DETECT FIRE	NO MEANS OF FIRE DETECTION ON BOARD SUB	DEATH, AIR CONTAMINATION, INJURY	IC	1	PROVIDE MEANS OF DETECTING FIRE IN THE INTERIOR.	IE	3	TBD	TIME DEPENDENT.
3.7.02B	INABILITY TO DETECT FIRE	IMPROPER DESIGN, SIZING, OR SELECTION OF FIRE DETECTION SYSTEM	DEATH, AIR CONTAMINATION, INJURY	IC	1	INSTALL APPROVED AND CERTIFIED FIRE DETECTION SYSTEM	IE	3	TBD	TIME DEPENDENT
3.7.02C	INABILITY TO DETECT FIRE	IMPROPER FABRICATION OR INSTALLATION OF FIRE DETECTION SYSTEM	DEATH, AIR CONTAMINATION, INJURY	IC	1	INSTALL APPROVED AND CERTIFIED FIRE DETECTION SYSTEM	IE	3	TBD	TIME DEPENDENT
3.7.02D	INABILITY TO DETECT FIRE	IMPROPER OR LACK OF MAINTENANCE TO FIRE DETECTION SYSTEM (SEE ALSO 6.4)	DEATH, AIR CONTAMINATION, INJURY	IC	1	PREVENTIVE MAINTENANCE PROGRAM.	IE	3	MTS I, SECTION G.5.0 &H, MTS II, SECTION J, ABS, SECTION B.45.	TIME DEPENDENT
3.7.02E	INABILITY TO DETECT FIRE	IMPROPER OPERATION OF FIRE DETECTION SYSTEM (SEE ALSO 6.1)	DEATH, AIR CONTAMINATION, INJURY	IC	2	EMERGENCY PROCEDURES. TRAINING PROGRAM.	iD	2	MTS III, SECTION B.4.6.1. TRAINING: MTS I, SECTION I.	TIME DEPENDENT
3.7.02F	INABILITY TO DETECT FIRE	MALFUNCTION OF FIRE DETECTION SYSTEM	DEATH, AIR CONTAMINATION, INJURY	IC	1	PROVIDE SYSTEM REDUNDANCY.	IE	3	TBD	TIME DEPENDENT

ELEMENT: SUBMERSIBLE
SYSTEM: SYSTEMS
SUBSYSTEM: EMERGENCY

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
3.7.03A	INABILITY TO CONTROL FLOODING	LEAKAGE OR FLOODING INTO CABIN	DROWNING, INABILITY TO SURFACE	IC	1	FOLLOW CFR TO PROVIDE BILGE SYSTEM OR EQUIVALENT SAFE MEASURES. PROVIDE BILGE PUMP AND DAMAGE CONTROL KIT. PROVIDE DAMAGE CONTROL KIT.	ID	2	46 CFR 182.25. PUMP, DAMAGE CONTROL KIT: TBD.	TIME DEPENDENT.
3.7.03B	INABILITY TO CONTROL FLOODING	IMPROPER DESIGN, SIZING, OR SELECTION OF BILGE SYSTEM	DROWNING, INABILITY TO SURFACE	IC	1	FOLLOW CFR FOR DESIGN AND SIZING OF BILGE SYSTEM OR EQUIVALENT SAFETY MEASURES. USCG PLAN REVIEW.	IE	3	46 CFR 182.25. USCG, MAY 87, P.3.	TIME DEPENDENT.
3.7.03C	INABILITY TO CONTROL FLOODING	IMPROPER FABRICATION OR INSTALLATION OF BILGE SYSTEM	DROWNING, INABILITY TO SURFACE	IC	1	FOLLOW CFR FOR BILGE SYSTEM OR EQUIVALENT SAFETY MEASURES. INSPECTION DURING MANUFACTURE.	IE	3	46 CFR 182.25. INSPECTION: 46 CFR 176.05, 176.10, ABS, SECTION C.17.	TIME DEPENDENT.
3.7.03D	INABILITY TO CONTROL FLOODING	IMPROPER OR LACK OF MAINTENANCE TO BILGE SYSTEM (SEE ALSO 6.4)	DROWNING, INABILITY TO SURFACE	IC	1	PREVENTIVE MAINTENANCE PROGRAM.	IE	3	ABS, SECTION B.45, MTS I, SECTION H, MTS II, SECTION J.	TIME DEPENDENT.
3.7.03E	INABILITY TO CONTROL FLOODING	IMPROPER OPERATION OF BILGE SYSTEM (SEE ALSO 6.1)	DROWNING, INABILITY TO SURFACE	IC	1	EMERGENCY PROCEDURES. TRAINING PROGRAM.	ID	2	EMER PROC: MTS III, SECTION B.4, TRAINING: MTS I, SECTION I.	TIME DEPENDENT.

ELEMENT: SUBMERSIBLE
SYSTEM: SYSTEMS
SUBSYSTEM: EMERGENCY

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
3.7.03F	INABILITY TO CONTROL FLOODING	LOSS OF PNEUMATIC POWER OR CONTROL TO BILGE SYSTEM (SEE ALSO 3.1)	DROWNING, INABILITY TO SURFACE	IC	1	CFR TO PROVIDE MANUALLY OPERATED BILGE PUMP OR EQUIVALENT SAFETY MEASURES.	IE	3	46 CFR 182.25	TIME DEPENDENT
3.7.03G	INABILITY TO CONTROL FLOODING	LOSS OF HYDRAULIC POWER OR CONTROL TO BILGE SYSTEM (SEE ALSO 3.2)	DROWNING, INABILITY TO SURFACE	IC	1	FOLLOW CFR TO PROVIDE MANUALLY OPERATED BILGE PUMP OR EQUIVALENT SAFETY MEASURES.	IE	3	46 CFR 182.25	TIME DEPENDENT
3.7.03H	INABILITY TO CONTROL FLOODING	LOSS OF ELECTRICAL POWER OR CONTROL TO BILGE SYSTEM (SEE ALSO 3.3)	DROWNING, INABILITY TO SURFACE	IC	1	FOLLOW CFR TO PROVIDE MANUALLY OPERATED BILGE PUMP OR EQUIVALENT SAFETY MEASURES.	IE	3	46 CFR 182.25	TIME DEPENDENT
3.7.03I	INABILITY TO CONTROL FLOODING	IMPROPER USE OF DAMAGE CONTROL KIT	DROWNING, INABILITY TO SURFACE	IC	1	PROVIDE PROPER OPERATING PROCEDURES (SEE SECTION 6.1.). TRAINING PROGRAM.	ID	2	OP PROC: MTS III, SECTION B.2, TRAINING: MTS I, SECTION I.	TIME DEPENDENT
3.7.03J	INABILITY TO CONTROL FLOODING	MALFUNCTION OF BILGE SYSTEM	DROWNING, INABILITY TO SURFACE	IC	1	FOLLOW CFR TO PROVIDE MANUALLY OPERATED BILGE PUMP OR EQUIVALENT SAFETY MEASURES.	IE	3	46 CFR 182.25	TIME DEPENDENT
3.7.03K	INABILITY TO CONTROL FLOODING	FAILURE TO SURFACE AT FIRST SIGN OF LEAKAGE	DROWNING, INABILITY TO SURFACE	IC	1	SUBMERSIBLE MUST SURFACE AT FIRST SIGN OF UNCONTROLLED LEAKING OR FLOODING PER MTS.	IE	3	MTS III, SECTION B.4.6.2.	

ELEMENT: SUBMERSIBLE
SYSTEM: SYSTEMS
SUBSYSTEM: EMERGENCY

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
3.7.04A	INABILITY TO DETECT FLOODING	LEAKAGE OR FLOODING INTO CABIN	DROWNING, INABILITY TO SURFACE	IC	2	PROVIDE FLOOD DETECTION SYSTEM.	IID	2	TBD	TIME DEPENDENT
3.7.04B	INABILITY TO DETECT FLOODING	IMPROPER DESIGN, SIZING, OR SELECTION OF FLOOD DETECTION SYSTEM	DROWNING, INABILITY TO SURFACE	IC	2	INSTALL APPROVED AND CERTIFIED FLOOD DETECTION SYSTEM. USCG PLAN REVIEW.	IIE	3	SYSTEM: TBD. USCG, MAY 87, P.3.	TIME DEPENDENT
3.7.04C	INABILITY TO DETECT FLOODING	IMPROPER FABRICATION OR INSTALLATION OF FLOOD DETECTION SYSTEM	DROWNING, INABILITY TO SURFACE	IC	2	INSPECTION DURING MANUFACTURE.	IIE	3	46 CFR 176.05, 176.10, ABS, SECTION C.17.	TIME DEPENDENT
3.7.04D	INABILITY TO DETECT FLOODING	IMPROPER OR LACK OF MAINTENANCE TO FLOOD DETECTION SYSTEM (SEE ALSO 6.4)	DROWNING, INABILITY TO SURFACE	IC	2	PREVENTIVE MAINTENANCE PROGRAM.	IIE	3	ABS, SECTION B.45, MTS I, SECTION H, MTS II, SECTION J.	TIME DEPENDENT
3.7.04E	INABILITY TO DETECT FLOODING	IMPROPER OPERATION OF FLOOD DETECTION SYSTEM (SEE ALSO 6.1)	DROWNING, INABILITY TO SURFACE	IC	2	EMERGENCY PROCEDURES. TRAINING PROGRAM.	IID	2	EMER PROC: MTS III, SECTION B.4. TRAINING: MTS I, SECTION I.	TIME DEPENDENT
3.7.04F	INABILITY TO DETECT FLOODING	LOSS OF PNEUMATIC POWER OR CONTROL TO FLOOD DETECTION SYSTEM (SEE ALSO 3.1)	DROWNING, INABILITY TO SURFACE	IC	2	PROVIDE FOR SYSTEM REDUNDANCY	IIE	3	TBD	TIME DEPENDENT
3.7.04G	INABILITY TO DETECT FLOODING	LOSS OF HYDRAULIC POWER OR CONTROL TO FLOOD DETECTION SYSTEM (SEE ALSO 3.2)	DROWNING, INABILITY TO SURFACE	IC	2	PROVIDE FOR SYSTEM REDUNDANCY	IIE	3	TBD	TIME DEPENDENT

ELEMENT: SUBMERSIBLE
SYSTEM: SYSTEMS
SUBSYSTEM: EMERGENCY

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
3.7.04H	INABILITY TO DETECT FLOODING	LOSS OF ELECTRICAL POWER OR CONTROL TO FLOOD DETECTION SYSTEM (SEE ALSO 3.3)	DROWNING, INABILITY TO SURFACE	IC	2	PROVIDE FOR SYSTEM REDUNDANCY	IIE	3	TBD	TIME DEPENDENT.
3.7.04I	INABILITY TO DETECT FLOODING	MALFUNCTION OF FLOOD DETECTION SYSTEM	DROWNING, INABILITY TO SURFACE	IC	2	PROVIDE FOR SYSTEM REDUNDANCY	IIE	3	TBD	TIME DEPENDENT.
3.7.05A	INABILITY TO JETTISON EMERGENCY BALLAST	IMPROPER DESIGN OR MATERIAL SELECTION FOR EMERGENCY DEBALLASTING SYSTEM	INABILITY TO SURFACE	IIC	2	FOLLOW ABS AND MTS FOR EMERGENCY DEBALLASTING SYSTEM.	IIE	3	ABS, SECTION 2.19.1. MTS I, SECTION E.4.1, SECTION G.7.1.	TIME DEPENDENT.
3.7.05B	INABILITY TO JETTISON EMERGENCY BALLAST	IMPROPER FABRICATION OR INSTALLATION OF EMERGENCY DEBALLASTING SYSTEM	INABILITY TO SURFACE	IIC	2	FOLLOW CFR, ABS, AND ASME FOR FABRICATION. INSPECTION DURING MANUFACTURE.	IIE	3	46 CFR 57. ABS, SECTION 1.3. ASME PVHO-1A, SECTION 1.3. INSPECTION: 46 CFR 176.05, 176.10, ABS, SECTION C.17.	TIME DEPENDENT.
3.7.05C	INABILITY TO JETTISON EMERGENCY BALLAST	IMPROPER OR LACK OF MAINTENANCE OR TESTING TO EMERGENCY DEBALLASTING SYSTEM (SEE ALSO 6.4)	INABILITY TO SURFACE	IIC	2	PREVENTIVE MAINTENANCE PROGRAM.	IIE	3	ABS, SECTION B.45, MTS I, SECTION H, MTS II, SECTION J.	TIME DEPENDENT.
3.7.05D	INABILITY TO JETTISON EMERGENCY BALLAST	IMPROPER OPERATION OF EMERGENCY DEBALLASTING SYSTEM (SEE ALSO 6.1)	INABILITY TO SURFACE	IIC	2	EMERGENCY PROCEDURES. TRAINING PROGRAM.	IID	2	EMER PROC: MTS III, SECTION B.4.6.6. TRAINING: MTS I, SECTION I.	TIME DEPENDENT.

ELEMENT: SUBMERSIBLE
SYSTEM: SYSTEMS
SUBSYSTEM: EMERGENCY

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
3.7.05E	INABILITY TO JETTISON EMERGENCY BALLAST	LOSS OF PNEUMATIC POWER OR CONTROL TO EMERGENCY DEBALLASTING SYSTEM (SEE ALSO 3.1)	INABILITY TO SURFACE	IIC	2	ABS & MTS TO PROVIDE COMPLETELY MANUALLY OPERATED SYSTEM FOR USE IN JETTISONING TRIM WEIGHT. PROVIDE SYSTEM REDUNDANCY.	IID	3	ABS, SECTION 2.19.1. MTS I, SECTION E.4.1 AND G.7.1. REDUNDANCY: TBD.	TIME DEPENDENT
3.7.05F	INABILITY TO JETTISON EMERGENCY BALLAST	LOSS OF HYDRAULIC POWER OR CONTROL TO EMERGENCY DEBALLASTING SYSTEM (SEE ALSO 3.2)	INABILITY TO SURFACE	IIC	2	FOLLOW ABS & MTS TO PROVIDE COMPLETELY MANUALLY OPERATED SYSTEM FOR USE IN JETTISONING TRIM WEIGHT. PROVIDE SYSTEM REDUNDANCY.	IID	3	ABS, SECTION 2.19.1. MTS I, SECTION E.4.1 AND G.7.1. REDUNDANCY: TBD.	TIME DEPENDENT
3.7.05G	INABILITY TO JETTISON EMERGENCY BALLAST	LOSS OF ELECTRICAL POWER OR CONTROL TO EMERGENCY DEBALLASTING SYSTEM (SEE ALSO 3.3)	INABILITY TO SURFACE	IIC	2	FOLLOW ABS & MTS TO PROVIDE COMPLETELY MANUALLY OPERATED SYSTEM FOR USE IN JETTISONING TRIM WEIGHT. PROVIDE SYSTEM REDUNDANCY.	IID	3	ABS, SECTION 2.19.1. MTS I, SECTION E.4.1 AND G.7.1. REDUNDANCY: TBD.	TIME DEPENDENT
3.7.05H	INABILITY TO JETTISON EMERGENCY BALLAST	MALFUNCTION OF RELEASING MECHANISM ON EMERGENCY DEBALLASTING SYSTEM	INABILITY TO SURFACE	IIC	2	FOLLOW ABS & MTS TO PROVIDE COMPLETELY MANUALLY OPERATED SYSTEM FOR USE IN JETTISONING TRIM WEIGHT. PROVIDE SYSTEM REDUNDANCY.	IID	3	ABS, SECTION 2.19.1. MTS I, SECTION E.4.1 AND G.7.1. REDUNDANCY: TBD.	TIME DEPENDENT

ELEMENT: SUBMERSIBLE
SYSTEM: SYSTEMS
SUBSYSTEM: EMERGENCY

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
3.7.05I	INABILITY TO JETTISON EMERGENCY BALLAST	SUB INCLINED AT TOO GREAT AN ANGLE TO ENABLE JETTISON TO RELEASE PROPERLY (SEE ALSO 2.1)	INABILITY TO SURFACE	IIC	2	FOLLOW MTS TO DESIGN TO JETTISON UNDER ALL SPECIFIED ANGLES OF PITCH AND ROLL. PROVIDE PROPER OPERATING PROCEDURES.	IIE	3	MTS I, SECTION E.4.2. OP PROC: MTS III, SECTION B.2.	TIME DEPENDENT
3.7.06A	LACK OF EMERGENCY POWER TO VITAL SYSTEMS	NO EMERGENCY POWER SYSTEM PROVIDED ON SUB	INABILITY TO SURFACE, AIR CONTAMINATION, COLLISION	IIC	2	FOLLOW ABS FOR DUPLICATE POWER SOURCES AND MTS FOR POWER LOSS CASUALTIES.	IIE	3	ABS, SECTION 7.27.2. MTS II, SECTION B.13.0.	TIME DEPENDENT
3.7.06B	LOSS OF EMERGENCY ELECTRICAL POWER TO VITAL SYSTEMS	IMPROPER DESIGN, SIZING, OR MATERIAL SELECTION FOR EMERGENCY POWER SYSTEM	INABILITY TO SURFACE, AIR CONTAMINATION, COLLISION	IIC	2	SIZE EMERGENCY POWER PER CFR. USCG PLAN REVIEW.	IIE	3	46 CFR 112.15. USCG, MAY 87, P.2.	TIME DEPENDENT
3.7.06C	LOSS OF EMERGENCY ELECTRICAL POWER TO VITAL SYSTEMS	IMPROPER FABRICATION OR INSTALLATION OF EMERGENCY ELECTRICAL SYSTEM	INABILITY TO SURFACE, AIR CONTAMINATION, COLLISION	IIC	2	FOLLOW CFR, ABS, MTS, AND NAVY FOR ELECTRICAL INSTALLATION. INSPECTION AND TESTING DURING MANUFACTURE AND FOR ACCEPTANCE.	IIE	3	46 CFR 183. ABS, SECTION 7. MTS II, SECTION B.9.0. NAVMAT P-9290, SECTION B.6. INSPECTION/TEST: 46 CFR 176.05, 176.10, ABS, SECTION C.17.	TIME DEPENDENT
3.7.06D	LOSS OF EMERGENCY ELECTRICAL POWER TO VITAL SYSTEMS	IMPROPER OR LACK OF MAINTENANCE TO EMERGENCY ELECTRICAL SYSTEM	INABILITY TO SURFACE, AIR CONTAMINATION, COLLISION	IIC	2	PREVENTIVE MAINTENANCE PROGRAM.	IIE	3	ABS, SECTION B.45, MTS I, SECTION H, MTS II, SECTION J.	TIME DEPENDENT

ELEMENT: SUBMERSIBLE
SYSTEM: SYSTEMS
SUBSYSTEM: EMERGENCY

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
3.7.06E	LOSS OF EMERGENCY ELECTRICAL POWER TO VITAL SYSTEMS	IMPROPER OPERATION OF EMERGENCY ELECTRICAL SYSTEM	INABILITY TO SURFACE, AIR CONTAMINATION, COLLISION	IIC	2	PROVIDE PROPER OPERATING PROCEDURES (SEE SECTION 6.1.). TRAINING PROGRAM.	IID	2	OP PROC: MTS III, SECTION B.2. TRAINING: MTS I, SECTION I.	TIME DEPENDENT.
3.7.07	LACK OF TOILET FACILITIES WHILE UNABLE TO SURFACE	INSUFFICIENT OR NO EMERGENCY TOILET FACILITIES ON BOARD SUB	ILLNESS, AIR CONTAMINATION	IIC	2	REQUIRE SUFFICIENT SANITARY FACILITIES FOR 72 HOURS. FOLLOW CFR FOR TOILET FACILITIES.	IID	2	SUFFICIENT FACILITIES: TBD. 46 CFR 177.30-5 AND 33 CFR 159	TIME DEPENDENT.
3.7.08A	INABILITY OF RESCUERS TO LOCATE SUB	LOSS OF VISUAL SIGHTING OR SONAR TRACKED POSITION OF SUB	INABILITY TO RESCUE SUB	IC	1	FOLLOW ABS AND MTS TO PROVIDE LOCATING DEVICES. PROVIDE PROPER OPERATING PROCEDURES (SEE SECTION 6.1). EMERGENCY BUOY.	IE	3	ABS, SECTION 2.7. MTS I, SECTION 4.0. OP PROC: MTS III, SECTION B.2. BUOY: TBD.	
3.7.08B	INABILITY OF RESCUERS TO LOCATE SUB	NO EMERGENCY MARKER BUOY PROVIDED ON SUB	INABILITY TO RESCUE SUB	IC	1	FOLLOW ABS AND MTS TO PROVIDE LOCATING DEVICES.	IE	3	ABS, SECTION 2.7. MTS I, SECTION 4.0.	
3.7.08C	INABILITY OF RESCUERS TO LOCATE SUB	IMPROPER FABRICATION OR INSTALLATION OF EMERGENCY MARKER BUOY	INABILITY TO RESCUE SUB	IC	1	INSPECT DURING MANUFACTURE.	IE	3	46 CFR 176.05, 176.10, ABS, SECTION C.17.	
3.7.08D	INABILITY OF RESCUERS TO LOCATE SUB	IMPROPER OR LACK OF MAINTENANCE TO EMERGENCY MARKER BUOY (SEE ALSO 6.4)	INABILITY TO RESCUE SUB	IC	1	PREVENTIVE MAINTENANCE PROGRAM.	IE	3	ABS, SECTION B.45, MTS I, SECTION H, MTS II, SECTION J.	

ELEMENT: SUBMERSIBLE
SYSTEM: SYSTEMS
SUBSYSTEM: EMERGENCY

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
3.7.08E	INABILITY OF RESCUERS TO LOCATE SUB	IMPROPER OPERATION OF EMERGENCY MARKER BUOY (SEE ALSO 6.1)	INABILITY TO RESCUE SUB	IC	1	EMERGENCY PROCEDURES. TRAINING PROGRAM.	ID	2	EMER PROC: MTS III, SECTION B.4.1B. TRAINING: MTS I, SECTION I.	
3.7.08F	INABILITY OF RESCUERS TO LOCATE SUB	NO EMERGENCY SONAR SYSTEM PROVIDED ON SURFACE SUPPORT VESSEL	INABILITY TO RESCUE SUB	IC	1	FOLLOW ABS & MTS TO PROVIDE LOCATING METHODS	IE	3	ABS, SECTION 2.7. MTS I, SECTION G.3.1.	
3.7.08G	INABILITY OF RESCUERS TO LOCATE SUB	IMPROPER DESIGN OF EMERGENCY SONAR SYSTEM ON SURFACE SUPPORT VESSEL	INABILITY TO RESCUE SUB	IC	1	FOLLOW ABS & MTS FOR RESCUE METHODS.	IE	3	ABS, SECTION 2.7. MTS III, SECTION B.4.3B	
3.7.08H	INABILITY OF RESCUERS TO LOCATE SUB.	IMPROPER FABRICATION OR INSTALLATION OF EMERGENCY SONAR SYSTEM ON SURFACE SUPPORT VESSEL	INABILITY TO RESCUE SUB	IC	1	INSPECTION DURING MANUFACTURE.	IE	3	MTS III, SECTION B.4.3B. 46 CFR 176.05, 176.10, ABS, SECTION C.17.	
3.7.08I	INABILITY OF RESCUERS TO LOCATE SUB.	IMPROPER OR LACK OF MAINTENANCE TO EMERGENCY SONAR SYSTEM ON SURFACE SUPPORT VESSEL (SEE ALSO 6.4)	INABILITY TO RESCUE SUB	IC	1	PREVENTIVE MAINTENANCE PROGRAM.	IE	3	ABS, SECTION B.45, MTS I, SECTION H, MTS II, SECTION J.	
3.7.08J	INABILITY OF RESCUERS TO LOCATE SUB.	IMPROPER OPERATION OF EMERGENCY SONAR SYSTEM ON SURFACE SUPPORT VESSEL (SEE ALSO 6.1)	INABILITY TO RESCUE SUB	IC	1	PROVIDE PROPER OPERATING PROCEDURES, TO INCLUDE SPECIFIC EMERGENCY PROCEDURES.	ID	2	MTS III, SECTION B.4.3B	

ELEMENT: SUBMERSIBLE
SYSTEM: SYSTEMS
SUBSYSTEM: EMERGENCY

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
3.7.08K	INABILITY OF RESCUERS TO LOCATE SUB	IMPROPER DESIGN OR SELECTION OF EMERGENCY MARKER BUOY	INABILITY TO RESCUE SUB	IC	1	FOLLOW ABS AND MTS TO PROVIDE LOCATING DEVICES.	IE	3	ABS, SECTION 2.7. MTS I, SECTION 4.0.	
3.7.09	OBJECTS UNSECURED WITHIN SUB DURING EMERGENCY ASCENT, UNCONTROLLED DESCENT, OR EVASIVE MANEUVERING	NO MEANS AVAILABLE FOR CREW TO SECURE OBJECTS PRIOR TO DIVE OR FOR PASSENGERS TO SECURE THEIR BELONGINGS	INJURY DUE TO FLYING OBJECTS	IIC	2	PROVIDE SECURING MEANS ON SUB SURFACE. PROVIDE PROPER OPERATING PROCEDURES.	IIE	3	SECURING MEANS: TBD. OP PROC: MTS III, SECTION B.2.	
3.7.10	OCCUPANTS NOT WEARING SEAT BELTS DURING EMERGENCY FREE ASCENT, UNCONTROLLED DESCENT, OR EVASIVE MANEUVERING	NO SEAT BELTS INSTALLED IN SUB	INJURY DUE TO FALL	IIC	2	PROVIDE SAFETY BELTS ON SUB. INFORM PASSENGERS OF SAFETY PROCEDURES. CHECK BELTS DAILY.	IIE	3	TBD	
3.7.11A	NO EMERGENCY MEANS OF BREATHING CLEAN AIR FOR PILOT	NO EMERGENCY MEANS OF BREATHING PROVIDED ON SUB	INABILITY TO SURFACE, INJURY	IID	2	FOLLOW MTS TO PROVIDE EMERGENCY BREATHING SYSTEM..	IIE	3	MTS 1, SECTION C.4.0	TIME DEPENDENT.
3.7.11B	NO EMERGENCY MEANS OF BREATHING CLEAN AIR FOR PILOT	IMPROPER DESIGN FOR EMERGENCY BREATHING SYSTEM	INABILITY TO SURFACE, INJURY	IIC	2	FOLLOW MTS TO PROVIDE EMERGENCY BREATHING SYSTEM. USCG PLAN REVIEW.	IIE	3	MTS I, SECTION C.4. USCG, MAY 87, P.3.	TIME DEPENDENT.
3.7.11C	NO EMERGENCY MEANS FOR BREATHING CLEAN AIR FOR PILOT	IMPROPER FABRICATION OR INSTALLATION OF EMERGENCY BREATHING SYSTEM	INABILITY TO SURFACE, INJURY	IIC	2	INSPECTION DURING MANUFACTURE.	IIE	3	46 CFR 176.05, 176.10, ABS, SECTION C.17.	TIME DEPENDENT.

ELEMENT: SUBMERSIBLE
SYSTEM: SYSTEMS
SUBSYSTEM: EMERGENCY

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
3.7.11D	NO EMERGENCY MEANS FOR BREATHING CLEAN AIR FOR PILOT	IMPROPER OR LACK OF MAINTENANCE TO EMERGENCY BREATHING SYSTEM (SEE ALSO 6.4)	INABILITY TO SURFACE, INJURY	IIC	2	PREVENTIVE MAINTENANCE PROGRAM.	IIE	3	ABS, SECTION B.45, MTS I, SECTION H, MTS II, SECTION J.	TIME DEPENDENT.
3.7.11E	NO EMERGENCY MEANS OF BREATHING CLEAN AIR FOR PILOT	IMPROPER OPERATION OF EMERGENCY BREATHING SYSTEM (SEE ALSO 6.1)	INABILITY TO SURFACE, INJURY	IIC	2	PROVIDE PROPER OPERATING PROCEDURES. TRAINING PROGRAM.	IID	2	OP PROC: MTS III, SECTION B.2. TRAINING: MTS I, SECTION I.	TIME DEPENDENT.
3.7.11F	NO EMERGENCY MEANS OF BREATHING CLEAN AIR FOR PILOT	LOSS OF AIR SUPPLY (SEE ALSO 3.1)	INABILITY TO SURFACE, COLLISION, *INJURY*	IIC	2	PROVIDE SYSTEM REDUNDANCY. PROVIDE PILOT *WITH EMERGENCY* "RESPIRATOR".	IIE	3	TBD	TIME DEPENDENT.
3.7.11G	CONTAMINATED EMERGENCY BREATHING CLEAN AIR FOR PILOT	EMERGENCY BREATHING AIR FOR PILOT IS NOT BREATHABLE GRADE AND IS NOT FILTERED PROPERLY	INABILITY TO SURFACE, COLLISION, INJURY	IIC	2	FOLLOW CFR FOR AIR QUALITY. PERIODIC CHECKS OF AIR QUALITY.	IID	2	46 CFR 197.340. AIR QUALITY CHECKS: TBD.	TIME DEPENDENT.
3.7.12A	NO EMERGENCY MEANS OI BREATHING CLEAN AIR FOR PASSENGERS	NO EMERGENCY MEANS OF BREATHING PROVIDED ON SUB	DEATH, INJURY	IC	1	FOLLOW MTS TO PROVIDE EMERGENCY BREATHING SYSTEM.	IE	3	MTS I, SECTION C.4.0. MTS III SECTION C.5.2.	TIME DEPENDENT.
3.7.12B	NO EMERGENCY MEANS OF BREATHING CLEAN AIR FOR PASSENGERS	IMPROPER DESIGN FOR EMERGENCY BREATHING SYSTEM	DEATH, INJURY	IC	1	FOLLOW MTS TO PROVIDE EMERGENCY BREATHING SYSTEM. USCG PLAN REVIEW.	IE	3	MTS I, SECTION C.4.0. MTS III, SECTION C.5.2. USCG, MAY 87, P.3.	TIME DEPENDENT.
3.7.12C	NO EMERGENCY MEANS OF BREATHING CLEAN AIR FOR PASSENGERS	IMPROPER FABRICATION OR INSTALLATION OF EMERGENCY BREATHING SYSTEM	DEATH, INJURY	IC	1	INSPECTION DURING MANUFACTURE.	IE	3	46 CFR 176.05, 176.10, ABS, SECTION C.17.	TIME DEPENDENT.

ELEMENT: SUBMERSIBLE
SYSTEM: SYSTEMS
SUBSYSTEM: EMERGENCY

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
3.7.12D	NO EMERGENCY MEANS OF BREATHING CLEAN AIR FOR PASSENGERS	IMPROPER OR LACK OF MAINTENANCE TO EMERGENCY BREATHING SYSTEM (SEE ALSO 6.4)	DEATH, INJURY	IC	1	PREVENTIVE MAINTENANCE PROGRAM.	IE	3	ABS, SECTION B.45, MTS I, SECTION H, MTS II, SECTION J.	TIME DEPENDENT.
3.7.12E	NO EMERGENCY MEANS OF BREATHING CLEAN AIR FOR PASSENGERS	IMPROPER OPERATION OF EMERGENCY BREATHING SYSTEM (SEE ALSO 6.1)	DEATH, INJURY	IC	1	PROVIDE PROPER OPERATING PROCEDURES, TO INCLUDE CFR TO ACQUAINT PASSENGERS WITH LIFE SAVING DEVICES.	ID	2	46 CFR 185.25-1, MTS III, SECTION B.2.	TIME DEPENDENT.
3.7.12F	NO EMERGENCY MEANS OF BREATHING CLEAN AIR FOR PASSENGERS	LOSS OF AIR SUPPLY (SEE ALSO 3.1) FOR EMERGENCY BREATHING	DEATH, INJURY	IC	1	FOLLOW NAVY TO MONITOR SUPPLY OF EMERGENCY BREATHING AIR. PROVIDE SYSTEM REDUNDANCY.	IE	3	NAVMAT P-9290, SECTION B.4.3 REDUNDANCY: TBD.	TIME DEPENDENT.
3.7.13	FIRE FIGHTING AGENT UNSUITED FOR CONFINED ATMOSPHERE	IMPROPER SELECTION OF FIGHTING AGENTS	AIR CONTAMINATION	IIC	2	FOLLOW ABS, NAVY, AND MTS FOR SELECTION OF FIRE EXTINGUISHING AGENTS SAFE FOR CONFINED ATMOSPHERE	IIE	3	ABS, SECTION 2.3. NAVMAT P-9290, SECTION B.4.4.1. MTS I, SECTION G.5.0.	TIME DEPENDENT

ELEMENT: SURFACE/SHORE
SYSTEM: SURFACE VESSELS
SUBSYSTEM: SURFACE SUPPORT VESSEL

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
4.1.01A	SURFACE SUPPORT VESSEL LOSES POSITION OF SUBMERGED SUB	IMPROPER DESIGN OR SELECTION OF TRACKING EQUIPMENT	COLLISION	IIC	2	INSTALL CERTIFIED SYSTEM.	IIE	3	MTS I, SECTION D.3.2. MTS III, SECTION B.2.3.1.	
4.1.01B	SURFACE SUPPORT VESSEL LOSES POSITION OF SUBMERGED SUB	IMPROPER FABRICATION OR INSTALLATION OF TRACKING EQUIPMENT	COLLISION	IIC	2	INSPECTION DURING FABRICATION	IIE	3	46 CFR 176.05, 176.10, ABS, SECTION C.17.	
4.1.01C	SURFACE SUPPORT VESSEL LOSES POSITION OF SUBMERGED SUB	IMPROPER OR LACK OF MAINTENANCE TO TRACKING EQUIPMENT (SEE ALSO 6.4)	COLLISION	IIC	2	PREVENTIVE MAINTENANCE PROGRAM.	IIE	3	ABS, SECTION B.45, MTS I, SECTION H, MTS II, SECTION J.	
4.1.01D	SURFACE SUPPORT VESSEL LOSES POSITION OF SUBMERGED SUB	IMPROPER OPERATION OF TRACKING EQUIPMENT (SEE ALSO 6.1)	COLLISION	IIC	2	PROVIDE PROPER OPERATING PROCEDURES. TRAINING PROGRAM.	IID	2	MTS I, SECTION J.4.1, MTS III, SXECTION B.2. TRAINING: MTS I, SECTION I.	
4.1.01E	SURFACE SUPPORT VESSEL LOSES POSITION OF SUBMERGED SUB	SUB OUT OF RANGE OF TRACKING EQUIPMENT ON SURFACE SUPPORT VESSEL	COLLISION	IIC	2	PROVIDE PROPER OPERATING PROCEDURES (SEE SECTION 6.1). ADEQUATE RANGE OF TRACKING SYSTEM DESIGN.	IID	2	OP PROC: MTS III, SECTION B.2. RANGE: TBD.	
4.1.02A	SURFACE SUPPORT VESSEL LOSES VISUAL SIGHTING OF SUB	CREW BECOMES DISTRACTED FROM VISUALLY TRACKING SUB	COLLISION	IIB	1	PROVIDE PROPER OPERATING PROCEDURES (SEE SECTION 6.1)	IIC	2	MTS III, SECTION B.2.	
4.1.02B	SURFACE SUPPORT VESSEL LOSES VISUAL SIGHTING OF SUB	INCREASE OF SEA STATE, DARKENING OF SKY, FOG, SQUALL	COLLISION	IIB	1	PROVIDE OPERATING PROCEDURES TO ACCOUNT FOR CHANGING WEATHER CONDITIONS.	IIC	2	MTS III, SECTION B.2.	

ELEMENT: SURFACE/SHORE
SYSTEM: SURFACE VESSELS
SUBSYSTEM: SURFACE SUPPORT VESSEL

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
4.1.03A	SURFACE SUPPORT VESSEL LOSES UNDERWATER COMMUNICATIONS WITH SUB	IMPROPER DESIGN OR SELECTION OF UNDERWATER COMMUNICATION SYSTEM	COLLISION	IIC	2	PROVIDE CERTIFIED UNDERWATER COMMUNICATION SYSTEM ON SURFACE SHIP. FOLLOW CFR, NAVY AND MTS FOR UNDERWATER COMMUNICATION SYSTEM.	IIE	3	CERTIFIED SYSTEM: TBD. 46 CFR 197.328. NAVMAT P-9290, B.4.4J. MTS I, SECTION G.3.1.	
4.1.03B	SURFACE SUPPORT VESSEL LOSES UNDERWATER COMMUNICATIONS WITH SUB	IMPROPER FABRICATION OR INSTALLATION OF UNDERWATER COMMUNICATION SYSTEM	COLLISION	IIC	2	INSPECTION DURING MANUFACTURE.	IIE	3	46 CFR 176.05, 176.10, ABS, SECTION C.17.	
4.1.03C	SURFACE SUPPORT VESSEL LOSES UNDERWATER COMMUNICATIONS WITH SUB	IMPROPER OR LACK OF MAINTENANCE TO UNDERWATER COMMUNICATION SYSTEM (SEE ALSO 6.4)	COLLISION	IIC	2	PREVENTIVE MAINTENANCE PROGRAM.	IIE	3	ABS, SECTION B.45, MTS I, SECTION H, MTS II, SECTION J.	
4.1.03D	SURFACE SUPPORT VESSEL LOSES UNDERWATER COMMUNICATIONS WITH SUB	IMPROPER OPERATION OF UNDERWATER COMMUNICATION SYSTEM (SEE ALSO 6.1)	COLLISION	IIC	2	PROVIDE PROPER OPERATING PROCEDURES. TRAINING PROGRAM.	IID	2	OP PROC: MTS III, SECTION B.2.4. TRAINING: MTS I, SECTION I.	
4.1.03E	SURFACE SUPPORT VESSEL LOSES UNDERWATER COMMUNICATIONS WITH SUB	LOSS OF BATTERY POWER TO UNDERWATER COMMUNICATION SYSTEM	COLLISION	IIC	2	FOLLOW MTS TO PROVIDE POWER BACK-UPS TO UNDERWATER COMMUNICATIONS. PROVIDE SYSTEM REDUNDANCY.	IIE	3	MTS I, SECTION J.4.2. REDUNDANCY: TBD.	

ELEMENT: SURFACE/SHORE
SYSTEM: SURFACE VESSELS
SUBSYSTEM: SURFACE SUPPORT VESSEL

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
4.1.03F	SURFACE SUPPORT VESSEL CANNOT ESTABLISH UNDERWATER COMMUNICATIONS WITH SUB	NO MEANS OF UNDERWATER COMMUNICATIONS INSTALLED ON BOARD SURFACE SUPPORT VESSEL	COLLISION	IID	2	FOLLOW CFR AND ABS FOR UNDERWATER COMMUNICATIONS.	IIE	3	46 CFR 197.328. ABS, SECTION 2.5.	
4.1.03G	SURFACE SUPPORT VESSEL LOSES UNDERWATER COMMUNICATIONS WITH SUB	SUB OUT OF RANGE OF SURFACE SUPPORT VESSEL UNDERWATER COMMUNICATIONS	COLLISION	IIC	2	PROVIDE PROPER OPERATING PROCEDURES (SEE SECTION 6.1). ENSURE COMMUNICATION SYSTEM HAS ADEQUATE RANGE.	IIE	3	MTS III, SECTION C.1.2. OP PROC: MTS III, SECTION B.2.	
4.1.03H	SURFACE SUPPORT VESSEL LOSES UNDERWATER COMMUNICATIONS WITH SUB	MALFUNCTION OF UNDERWATER COMMUNICATION SYSTEM ON SURFACE SUPPORT VESSEL	COLLISION	IIC	2	PROVIDE SYSTEM REDUNDANCY.	IIE	3	MTS III, SECTION C.1.2.	
4.1.04A	LOSS OF SURFACE COMMUNICATIONS	IMPROPER DESIGN OR SELECTION OF SURFACE COMMUNICATION SYSTEM	COLLISION	IIC	2	FOLLOW CFR FOR RADIOS	IIE	3	46 CFR 184.25	
4.1.04B	LOSS OF SURFACE COMMUNICATIONS	IMPROPER INSTALLATION OF SURFACE COMMUNICATION SYSTEM	COLLISION	IIC	2	FOLLOW CFR FOR RADIOS. INSPECTION DURING MANUFACTURE.	IIE	3	46 CFR 184.25. INSPECTION: 46 CFR 176.05, 176.10, ABS, SECTION C.17.	

ELEMENT: SURFACE/SHORE
SYSTEM: SURFACE VESSELS
SUBSYSTEM: SURFACE SUPPORT VESSEL

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
4.1.04C	LOSS OF SURFACE COMMUNICATIONS	IMPROPER OR LACK OF MAINTENANCE TO SURFACE COMMUNICATION SYSTEM (SEE ALSO 6.4)	COLLISION	IIC	2	PREVENTIVE MAINTENANCE PROGRAM. REQUIRE TESTING OF COMMUNICATION SYSTEM PRIOR TO EACH DIVE.	IIE	3	ABS, SECTION B.45, MTS I, SECTION H, MTS II, SECTION J. MTS III, SECTION B.2.4.	
4.1.04D	LOSS OF SURFACE COMMUNICATIONS	IMPROPER OPERATION OF SURFACE COMMUNICATION SYSTEM (SEE ALSO 6.1)	COLLISION	IIC	2	PROVIDE PROPER OPERATING PROCEDURES. TRAINING PROGRAM.	IID	2	OP PROC: MTS III, SECTION B.2. TRAINING: MTS I, SECTION I.	
4.1.04E	LACK OF SURFACE COMMUNICATIONS	NO MEANS OF SURFACE COMMUNICATIONS INSTALLED ON BOARD SURFACE SUPPORT VESSEL	COLLISION	IID	2	FOLLOW CFR FOR RADIOS	IIE	3	46 CFR 184.25	
4.1.04F	LOSS OF SURFACE COMMUNICATIONS	SUB OUT OF RANGE OF SURFACE COMMUNICATIONS OF SURFACE SUPPORT VESSEL	COLLISION	IIC	2	PROVIDE PROPER OPERATING AND EMERGENCY PROCEDURES (SEE SECTIONS 6.1 AND 6.1). ENSURE SYSTEM HAS ADEQUATE CAPABILITIES AND RANGE, SUCH AS A HIGH POWERED FLASHING LIGHT.	IID	2	MTS III, SECTION B.4.6.7. CAPABILITIES: TBD.	
4.1.04G	LOSS OF SURFACE COMMUNICATIONS	MALFUNCTION OF SURFACE COMMUNICATION SYSTEM	COLLISION	IIC	2	PROVIDE SYSTEM REDUNDANCY, SUCH AS BACK-UP POWER TO SURFACE COMMUNICATIONS.	IIE	3	MTS I, SECTION J.4.2.	

ELEMENT: SURFACE/SHORE
SYSTEM: SURFACE VESSELS
SUBSYSTEM: SURFACE SUPPORT VESSEL

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
4.1.04H	LOSS OF SURFACE COMMUNICATIONS	LOSS OF POWER TO SURFACE COMMUNICATION SYSTEM	COLLISION	IIC	2	FOLLOW ABS TO PROVIDE POWER FROM EMERGENCY BATTERY TO SURFACE COMMUNICATIONS. PROVIDE SYSTEM REDUNDANCY.	IIE	3	ABS, SECTION 7.27. REDUNDANCY: TBD.	
4.1.05A	SURFACE SUPPORT VESSEL FAILS TO MAINTAIN CONTROL OVER SUB OPERATING AREA	MORE THAN ONE SUB IN OPERATING AREA	COLLISION	IIC	1	RESTRICT 1 SUB TO EACH AREA. PROVIDE PROPER OPERATING PROCEDURES.	IIE	3	MTS III, SECTION B.1.6.2(7). OP PROC: MTS III, SECTION B.2.	
4.1.05B	BOATS IN IMMEDIATE AREA OF SUB	SURFACE SUPPORT VESSEL FAILS TO MAINTAIN CONTROL OVER SUB OPERATING AREA	COLLISION	IIB	1	MAINTAIN CONTROL OVER OPERATING AREA. PROVIDE PROPER OPERATING PROCEDURES.	IIE	3	MTS III, SECTION B.1.6.2(7). OP PROC: MTS III, SECTION B.2.	
4.1.06	EMERGENCY EVACUATION OF PASSENGERS FROM SUB INTO WATER	LACK OF MEANS TO RESCUE PASSENGERS FROM WATER	DROWNING	ID	2	FOLLOW CFR IN PROVIDING LIFE JACKETS OR RAFTS FOR NO LESS THAN CAPACITY OF SUB	IE	3	46 CFR 180	

ELEMENT: SURFACE/SHORE
SYSTEM: SURFACE VESSELS
SUBSYSTEM: PASSENGER TAXI VESSEL

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
4.2.01A	GANGWAY BETWEEN PASSENGER TAXI VESSEL AND DOCK OR SUB IS UNSTABLE OR SLICK	IMPROPER DESIGN OR MATERIAL SELECTION FOR GANGWAY	DROWNING, INJURY DUE TO FALL	IC	1	EVALUATE DESIGN FOR SAFETY OF PASSENGER TRANSFER.	IE	3	TBD	
4.2.01B	GANGWAY BETWEEN PASSENGER TAXI VESSEL AND DOCK OR SUB IS UNSTABLE OR SLICK	IMPROPER FABRICATION OF GANGWAY	DROWNING, INJURY DUE TO FALL	IC	1	INSPECTION DURING MANUFACTURE. ACCEPTANCE TESTING.SELECTION CRITERIA	IE	3	46 CFR 176.05, 176.10, ABS, SECTION C.17.	
4.2.01C	GANGWAY BETWEEN PASSENGER TAXI VESSEL AND DOCK OR SUB IS UNSTABLE OR SLICK	IMPROPER OR LACK OF MAINTENANCE TO GANGWAY (SEE ALSO 6.4)	DROWNING, INJURY DUE TO FALL	IC	1	PREVENTIVE MAINTENANCE PROGRAM.	IE	3	ABS, SECTION B.45, MTS I, SECTION H, MTS II, SECTION J.	
4.2.01D	GANGWAY BETWEEN PASSENGER TAXI VESSEL AND DOCK OR SUB IS UNSTABLE OR SLICK	IMPROPER USAGE OR SECUREMENT OF GANGWAY (SEE ALSO 6.1)	DROWNING, INJURY DUE TO FALL	IB	1	PROVIDE PROPER OPERATING PROCEDURES (SEE SECTION 6.1).	IE	3	MTS III, SECTION B.2.	
4.2.02	PASSENGERS FALL DURING TRANSFER BETWEEN PASSENGER TAXI VESSEL AND DOCK OR SUB	LACK OF PROPER MEANS TO TRANSFER PASSENGERS BETWEEN PASSENGER TAXI VESSEL AND DOCK OR SUB	DROWNING, INJURY DUE TO FALL	IB	1	PROVIDE PROPER SAFE TRANSFERRING MEANS FOR PASSENGERS.	ID	2	TBD	

ELEMENT: SURFACE/SHORE
SYSTEM: SHORE FACILITIES
SUBSYSTEM: DOCKING FACILITIES

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
5.1.01A	DOCK IS UNEVEN OR SLICK	IMPROPER DESIGN OR CONSTRUCTION OF DOCK	DROWNING, INJURY DUE TO FALL	IC	1	DOCK CERTIFICATION BEFORE USAGE.	IE	3	TBD	
5.1.01B	DOCK IS UNEVEN OR SLICK	LACK OF MAINTENANCE TO DOCK	DROWNING, INJURY DUE TO FALL	IC	1	PREVENTIVE MAINTENANCE PROGRAM.	1D	2	ABS, SECTION B.45, MTS I, SECTION H, MTS II, SECTION J.	
5.1.02A	DOCK DOES NOT PROVIDE ADEQUATE ACCESS FOR SUB OPERATIONS	IMPROPER CHOICE OF DOCKING SITE	DROWNING, INJURY DUE TO FALL, COLLISION	IC	1	CERTIFY DOCK SITE BEFORE OPERATION.	ID	2	TBD	
5.1.02B	DOCK DOES NOT PROVIDE ADEQUATE ACCESS FOR SUB OPERATIONS	DOCKING SITE OPERATIONS NOT PROPERLY CONTROLLED	DROWNING, INJURY DUE TO FALL, COLLISION	IC	1	PROVIDE CONTROLLING PROCEDURES FOR DOCKING AREA. TRAINING PROGRAM.	ID	2	CONTROLLING PROC: TBD. TRAINING: MTS I, SECTION I.	

ELEMENT: SURFACE/SHORE
SYSTEM: SHORE FACILITIES
SUBSYSTEM: MAINTENANCE FACILITIES

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
5.2.01A	GANGWAY BETWEEN MAINTENANCE AREA AND SUB IS UNSTABLE OR SLICK	IMPROPER DESIGN OR MATERIAL SELECTION FOR GANGWAY	DROWNING, INJURY DUE TO FALL	IC	1	CERTIFY GANGWAY DESIGN PRIOR TO OPERATION	IE	3	TBD.	
5.2.01B	GANGWAY BETWEEN MAINTENANCE AREA AND SUB IS UNSTABLE OR SLICK	IMPROPER FABRICATION OF GANGWAY	DROWNING, INJURY DUE TO FALL	IC	1	INSPECTION DURING MANUFACTURE.	IE	3	46 CFR 176.05, 176.10, ABS, SECTION C.17.	
5.2.01C	GANGWAY BETWEEN MAINTENANCE AREA AND SUB IS UNSTABLE OR SLICK	IMPROPER OR LACK OF MAINTENANCE TO GANGWAY	DROWNING, INJURY DUE TO FALL	IC	1	PREVENTIVE MAINTENANCE PROGRAM.	IE	3	ABS, SECTION B.45, MTS I, SECTION H, MTS II, SECTION J.	
5.2.01D	GANGWAY BETWEEN MAINTENANCE AREA AND SUB IS UNSTABLE OR SLICK	IMPROPER USAGE OF GANGWAY	DROWNING, INJURY DUE TO FALL	IC	1	PROVIDE PROPER OPERATING PROCEDURES (SEE SECTION 6.1).	ID	2	MTS III, SECTION B.2.	
5.2.02	MAINTENANCE PERSONNEL FALL DURING TRANSFER BETWEEN DOCK AND SUB	LACK OF PROPER MEANS TO GET BETWEEN DOCK AND SUB	DROWNING, INJURY DUE TO FALL	IC	1	PROVIDE SAFE TRANSFER MEANS FOR PERSONNEL.	ID	2	TBD	

ELEMENT: SURFACE/SHORE
SYSTEM: SHORE FACILITIES
SUBSYSTEM: EMERGENCY FACILITIES

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
5.3.01A	LIFTING DEVICE UNABLE TO RETRIEVE SUB FROM SEABED	LIFTING DEVICE IS UNAVAILABLE FOR USE IN RETRIEVAL OPERATIONS	INABILITY TO LIFT SUB TO SURFACE	IIC	2	PROVIDE ALTERNATE MEANS OF SUB RETREIVAL.	IID	2	TBD	TIME DEPENDENT.
5.3.01B	LIFTING DEVICE UNABLE TO RETRIEVE SUB FROM SEABED	IMPROPER RETRIEVAL PROCEDURES BY OPERATOR OF LIFTING DEVICE	INABILITY TO LIFT SUB TO SURFACE	IIC	2	PROVIDE PROPER RETREIVAL PROCEDURES TO ALL PARTIES.	IID	2	MTS III, SECTION C.1.7.	TIME DEPENDENT.
5.3.01C	LIFTING DEVICE UNABLE TO RETRIEVE SUB FROM SEABED	FAILURE OF LIFTING POINT ATTACHMENT (SEE ALSO 1.3.06)	INABILITY TO LIFT SUB TO SURFACE	IIC	2	PROPER DESIGN CONSIDERATIONS. WEIGHT TESTING OF LIFTING ATTACHMENTS.	IIE	3	TBD	TIME DEPENDENT.
5.3.01D	LIFTING DEVICE UNABLE TO RETRIEVE SUB FROM SEABED	LIFTING CAPACITY OF DEVICE IS INSUFFICIENT TO RETRIEVE SUB	INABILITY TO LIFT SUB TO SURFACE	IIC	2	PROVIDE LIFTING DEVICE WITH ADEQUATE LIFTING CAPACITY. ACCEPTANCE TESTING OF DEVICE.	IID	2	MTS II, SECTION G.4.0.	TIME DEPENDENT.
5.3.01E	LIFTING DEVICE UNABLE TO RETRIEVE SUB FROM SEABED	FAILURE OF LIFTING DEVICE	INABILITY TO LIFT SUB TO SURFACE	IIC	2	PROVIDE LIFTING DEVICE CAPABLE OF RESCUE OPERATIONS. PERIODIC CHECKING OF LIFTING DEVICE FOR ADEQUACY. ACCEPTANCE TESTING OF LIFTING DEVICE.	IIE	3	MTS II, SECTION G.4.0.	
5.3.02A	RESCUE VEHICLE UNABLE TO RETRIEVE SUB FROM SEABED OR ENTANGLEMENT	RESCUE VEHICLE IS UNAVAILABLE FOR USE IN RETRIEVAL OPERATIONS	INABILITY TO LIFT SUB TO SURFACE	IIC	2	EMERGENCY PREPARED PLANNING SHOULD INCLUDE CONTINGENCY.	IID	2	MTS II, SECTION E.5.	TIME DEPENDENT.

ELEMENT: SURFACE/SHORE
SYSTEM: SHORE FACILITIES
SUBSYSTEM: EMERGENCY FACILITIES

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
5.3.02B	RESCUE VEHICLE UNABLE TO RETRIEVE SUB FROM SEABED OR ENTANGLEMENT	IMPROPER RETRIEVAL PROCEDURES BY RESCUE VEHICLE OPERATOR	INABILITY TO LIFT SUB TO SURFACE	IIC	2	TRAINING PROGRAM. PROVIDE SAFE OPERATING PROCEDURES TO ALL PARTIES.	IID	2	TRAINING: MTS I, SECTION I. OP PROC: MTS III, SECTION B.2.	TIME DEPENDENT
5.3.02C	RESCUE VEHICLE UNABLE TO RETRIEVE SUB FROM SEABED OR ENTANGLEMENT	FAILURE OF LIFTING POINT ATTACHMENT (SEE ALSO 1.3.06)	INABILITY TO LIFT SUB TO SURFACE	IIC	2	PROPER DESIGN AND TESTING OF ATTACHMENTS.	IIE	3	TBD	TIME DEPENDENT
5.3.02D	RESCUE VEHICLE UNABLE TO RETRIEVE SUB FROM SEABED OR ENTANGLEMENT	LIFTING CAPACITY OF RESCUE VEHICLE IS INSUFFICIENT TO RETRIEVE SUB	INABILITY TO LIFT SUB TO SURFACE	IIC	2	PROVIDE RESCUE VEHICLE WITH ADEQUATE LIFTING CAPACITY. PROVIDE WEIGHT TESTING OF RESCUE VEHICLE.	IID	2	MTS II, SECTION G.4.8.	TIME DEPENDENT

ELEMENT: GENERAL
SYSTEM: DOCUMENTATION
SUBSYSTEM: OPERATING PROCEDURES

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
6.1.01A	PROPER PROCEDURES ARE NOT CARRIED OUT FOR OPERATION OF SUB	NO OPERATIONS MANUAL FOR PARTICULAR SUB	FLOODING, COLLISION, AIR CONTAMINATION, INABILITY TO SURFACE, FIRE	IIC	2	FOLLOW MTS, ABS, NAVY, AND USCG TO PROVIDE OPERATING MANUAL.	IIE	3	MTS III, SECTION A.1.2.5. ABS, SECTION 1.17.1. NAVMAT P-9290, SECTION 7.4. USCG, MAY 87, P.4.	TIME DEPENDENT
6.1.01B	PROPER PROCEDURES ARE NOT CARRIED OUT FOR OPERATION OF SUB	INCORRECT, INACCURATE, OR INCOMPLETE OPERATIONS MANUAL	FLOODING, COLLISION, AIR CONTAMINATION, INABILITY TO SURFACE, FIRE	IIC	2	FOLLOW MTS, ABS, AND NAVY TO PROVIDE OPERATING MANUAL. PROVIDE CONFIGURATION MANAGEMENT.	IID	2	MTS III, SECTION A.1.2.5, B.2. ABS, SECTION 1.17.1. NAVMAT P-9290, SECTION 7.4. CONFIG MGMT: TBD.	TIME DEPENDENT
6.1.01C	PROPER PROCEDURES ARE NOT CARRIED OUT FOR OPERATION OF SUB	CREW FAILS TO FOLLOW OPERATIONS MANUAL	FLOODING, COLLISION, AIR CONTAMINATION, INABILITY TO SURFACE, FIRE	IIB	1	CHECKLISTS AND LOGS. TRAINING PROGRAM.	IID	2	MTS III, SECTION A.1.2.5, SECTION B.2.1, AND APPENDIX I. TRAINING: MTS I, SECTION I.	TIME DEPENDENT
6.1.02A	PROPER PROCEDURES ARE NOT CARRIED OUT FOR HANDLING OF PASSENGERS DURING TRANSFER	OPERATIONS MANUAL FOR PARTICULAR SUB	DROWNING, INJURY	IC	1	PROVIDE PROPER OPERATING PROCEDURES FOR PASSENGER TRANSFER.	IE	3	MTS III, SECTION B.2. USCG, MAY 87, P.4.	
6.1.02B	PROPER PROCEDURES ARE NOT CARRIED OUT FOR HANDLING OF PASSENGERS DURING TRANSFER	INCORRECT, INACCURATE, OR INCOMPLETE OPERATIONS MANUAL	DROWNING, INJURY	IC	1	PROVIDE PROPER OPERATING PROCEDURES FOR PASSENGER TRANSFER. PROVIDE CONFIGURATION MANAGEMENT	ID	2	OP PROC: MTS III, SECTION B.2. CONFIG MGMT: TBD.	

ELEMENT: GENERAL
SYSTEM: DOCUMENTATION
SUBSYSTEM: OPERATING PROCEDURES

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
6.1.02C	PROPER PROCEDURES ARE NOT CARRIED OUT FOR HANDLING OF PASSENGERS DURING TRANSFER	CREW FAILS TO FOLLOW OPERATIONS MANUAL	DROWNING, INJURY	IC	1	TRAINING PROGRAM.	ID	2	MTS I, SECTION I.	
6.1.03A	PROPER PROCEDURES ARE NOT CARRIED OUT FOR OPERATION OF LIFE SUPPORT EQUIPMENT	NO OPERATIONS MANUAL FOR PARTICULAR SUB	DEATH, INJURY, AIR CONTAMINATION	IC	1	FOLLOW ABS, NAVY, AND USCG TO PROVIDE OPERATING MANUAL.	IE	3	ABS, SECTION 1.17.1. NAVMAT P-9290, SECTION 7.4. USCG, MAY 87, P.4.	TIME DEPENDENT
6.1.03B	PROPER PROCEDURES ARE NOT CARRIED OUT FOR OPERATION OF LIFE SUPPORT EQUIPMENT	INCORRECT, INACCURATE, OR INCOMPLETE OPERATIONS MANUAL	DEATH, INJURY, AIR CONTAMINATION	IC	1	FOLLOW ABS, NAVY, AND MTS TO PROVIDE OPERATING MANUAL. PROVIDE CONFIGURATION MANAGEMENT.	ID	2	ABS, SECTION 1.17.1. NAVMAT P-9290, SECTION 7.4. MTS III, SECTION B.2. CONFIG MGMT: TBD.	TIME DEPENDENT
6.1.03C	PROPER PROCEDURES ARE NOT CARRIED OUT FOR OPERATION OF LIFE SUPPORT EQUIPMENT	CREW FAILS TO FOLLOW OPERATIONS MANUAL	DEATH, INJURY, AIR CONTAMINATION	IC	1	TRAINING PROGRAM. CHECKLISTS AND LOGS.	ID	2	TRAINING: MTS I, SECTION I. MTS III, SECTION B.2.1 AND APPENDIX I.	TIME DEPENDENT

ELEMENT: GENERAL
SYSTEM: DOCUMENTATION
SUBSYSTEM: EMERGENCY PROCEDURES

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
6.2.01A	PROPER PROCEDURES ARE NOT CARRIED OUT FOR EMERGENCY ASCENT, RESCUE, EVACUATION, FIRE, FLOODING, COLLISION, AIR CONTAMINATION	NO EMERGENCY PROCEDURES WRITTEN FOR PARTICULAR SUB	DEATH OR INJURY TO OCCUPANTS	IC	1	FOLLOW ABS, NAVY, AND USCG TO INCLUDE EMERGENCY PROCEDURES IN OPERATING MANUAL.	IE	3	ABS, SECTION 1.17.1. NAVMAT P-9290, SECTION 7.4. USCG, MAY 87, P.4.	TIME DEPENDENT
6.2.01B	PROPER PROCEDURES ARE NOT CARRIED OUT FOR EMERGENCY ASCENT, RESCUE, EVACUATION, FIRE, FLOODING, COLLISION, AIR CONTAMINATION	INCORRECT, INACCURATE, OR INCOMPLETE EMERGENCY PROCEDURE DOCUMENTATION	DEATH OR INJURY TO OCCUPANTS	IC	1	FOLLOW ABS AND NAVY TO INCLUDE EMERGENCY PROCEDURES IN OPERATING MANUAL. PROVIDE CONFIGURATION MANAGEMENT.	ID	2	ABS, SECTION 1.17.1. NAVMAT P-9290, SECTION 7.4. MTS III, SECTION B.4. CONFIG MGMT: TBD.	TIME DEPENDENT
6.2.01C	PROPER PROCEDURES ARE NOT CARRIED OUT FOR EMERGENCY ASCENT, RESCUE, EVACUATION, FIRE, FLOODING, COLLISION, AIR CONTAMINATION	CREW FAILS TO FOLLOW EMERGENCY PROCEDURE DOCUMENTATION	DEATH OR INJURY TO OCCUPANTS	IC	1	TRAINING PROGRAM. EMERGENCY PROCEDURE CARDS/ FOLDER FOR PILOT.	ID	2	TRAINING: MTS I, SECTION I. MTS III, SECTION B.4.7.	TIME DEPENDENT
6.2.01D	PROPER PROCEDURES ARE NOT CARRIED OUT FOR EMERGENCY ASCENT, RESCUE, EVACUATION, FIRE, FLOODING, COLLISION, AIR CONTAMINATION	NO EMERGENCY PROCEDURES WRITTEN FOR PARTICULAR OPERATING AREA	DEATH OR INJURY TO OCCUPANTS	IC	1	FOLLOW ABS AND NAVY TO INCLUDE EMERGENCY PROCEDURES FOR ALL SITUATIONS, INCLUDING LIMITED OPERATING AREA.	IE	3	ABS, SECTION 1.17.1. NAVMAT P-9290, SECTION 7.4.	TIME DEPENDENT

ELEMENT: GENERAL
SYSTEM: DOCUMENTATION
SUBSYSTEM: EMERGENCY PLANS

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
6.3.01A	PROPER EMERGENCY PLAN NOT CARRIED OUT FOR EMERGENCY ASCENT, RESCUE, EVACUATION, FIRE, FLOODING, COLLISION, OR AIR CONTAMINATION	NO EMERGENCY PLAN FOR PARTICULAR SUB	FLOODING, COLLISION, AIR CONTAMINATION, INABILITY TO SURFACE, FIRE	IIC	1	PROVIDE EMERGENCY PLAN FOR SYSTEM.	IIE	3	MTS III, SECTION B.3.09. USCG, MAY 87, P.4.	TIME DEPENDENT
6.3.01B	PROPER EMERGENCY PLAN NOT CARRIED OUT FOR EMERGENCY ASCENT, RESCUE, EVACUATION, FIRE, FLOODING, COLLISION, OR AIR CONTAMINATION	NO EMERGENCY PLAN FOR PARTICULAR OPERATING AREA	FLOODING, COLLISION, AIR CONTAMINATION, INABILITY TO SURFACE, FIRE	IIC	1	PREPARE EMERGENCY PLAN FOR EACH AREA.	IIE	3	MTS III, SECTION B.3.	TIME DEPENDENT
6.3.01C	PROPER EMERGENCY PLAN NOT CARRIED OUT FOR EMERGENCY ASCENT, RESCUE, EVACUATION, FIRE, FLOODING, COLLISION, OR AIR CONTAMINATION	INACCURATE OR INCOMPLETE EMERGENCY PLAN	FLOODING, COLLISION, AIR CONTAMINATION, INABILITY TO SURFACE, FIRE	IIC	1	PROVIDE EMERGENCY PLAN FOR SYSTEM. PROVIDE CONFIGURATION MANAGEMENT.	IIC	2	MTS III, SECTION B.3. CONFIG MGMT: TBD.	TIME DEPENDENT
6.3.01D	PROPER EMERGENCY PLAN NOT CARRIED OUT FOR EMERGENCY ASCENT, RESCUE, EVACUATION, FIRE, FLOODING, COLLISION, OR AIR CONTAMINATION	CREW FAILS TO FOLLOW EMERGENCY PLAN	FLOODING, COLLISION, AIR CONTAMINATION, INABILITY TO SURFACE, FIRE	IIC	1	TRAINING PROGRAM. DRILLS.	IIC	2	TRAINING: MTS I, SECTION . DRILLS: TBD.	TIME DEPENDENT

ELEMENT: GENERAL
SYSTEM: DOCUMENTATION
SUBSYSTEM: MAINTENANCE PROCEDURES

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
6.4.01A	PROPER MAINTENANCE PROCEDURES NOT CARRIED OUT FOR A PARTICULAR SUBSYSTEM OF SUB	NO MAINTENANCE PLAN FOR PARTICULAR SUB	FLOODING, COLLISION, AIR CONTAMINATION, INABILITY TO SURFACE, FIRE	IIC	2	PREVENTIVE MAINTENANCE PROGRAM. FOLLOW ABS AND NAVY TO PROVIDE MAINTENANCE MANUAL.	IIE	3	ABS, SECTION 1.17.2, B.45. NAVMAT P-9290, SECTION 7.5. MTS I, SECTION H, MTS II, SECTION J.	TIME DEPENDENT.
6.4.01B	PROPER MAINTENANCE PROCEDURES NOT CARRIED OUT FOR ANY SUBSYSTEMS OF SUB	INACCURATE OR INCOMPLETE MAINTENANCE PLAN FOR SUB	FLOODING, COLLISION, AIR CONTAMINATION, INABILITY TO SURFACE, FIRE	IIC	2	PREVENTIVE MAINTENANCE PROGRAM TO INCLUDE ABS AND NAVY TO PROVIDE MAINTENANCE MANUAL. PROVIDE CONFIGURATION MANAGEMENT.	IID	2	ABS, SECTION 1.17.2. NAVMAT P-9290, SECTION 7.5. MTS I, SECTION H, MTS II, SECTION J. CONFIG MGMT: TBD.	TIME DEPENDENT
6.4.01C	PROPER MAINTENANCE PROCEDURES NOT CARRIED OUT FOR ANY SUBSYSTEMS OF SUB	MAINTENANCE CREW FAILS TO FOLLOW MAINTENANCE PLAN FOR SUB	FLOODING, COLLISION, AIR CONTAMINATION, INABILITY TO SURFACE, FIRE	IIC	2	TRAINING PROGRAM AS PER MTS. DAILY MAINTENANCE CHECKLISTS AND RECORD SHEETS.	IID	2	MTS II, SECTION D.5. MTS III, APPENDIX I, SECTION 2.0. MTS II, SECTION J.4.	TIME DEPENDENT

ELEMENT: GENERAL
SYSTEM: PEOPLE
SUBSYSTEM: QUALIFICATIONS

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
7.1.01A	PILOT IS NOT QUALIFIED TO PILOT SUB	NO GUIDELINES FOR QUALIFICATION OF PILOTS	IMPROPER OPERATION OF SUB	IIC	2	FOLLOW MTS, DSP, AND CFR TO DEVELOP QUALIFICATIONS FOR PILOTS.	IIE	3	MTS I, SECTION I.4.5. MTS II, SECTION 4.3. MTS III, SECTION A.1.3. DSPA, SECTION IV.- 46 CFR 157.	
7.1.01B	PILOT IS NOT QUALIFIED TO PILOT SUB	GUIDELINES FOR QUALIFICATION OF PILOTS NOT FOLLOWED	IMPROPER OPERATION OF SUB	IIC	2	FOLLOW CFR, MTS, AND DSPA TO DEVELOP QUALIFICATIONS FOR PILOTS.	IID	2	46 CFR 157. MTS I, SECTION I.4.5. MTS II, SECTION 4.3. MTS III, SECTION A.1.3. DSPA, SECTION IV.	
7.1.02A	MAINTENANCE PERSONNEL ARE NOT QUALIFIED	NO GUIDELINES FOR QUALIFICATION OF MAINTENANCE PERSONNEL	IMPROPER MAINTENANCE OF SUB	IIC	2	ENSURE MAINTENANCE PERSONNEL POSSESS MINIMUM QUALIFICATIONS.	IIE	3	46 CFR 157. MTS III, SECTION A.1.3.	
7.1.02B	MAINTENANCE PERSONNEL ARE NOT QUALIFIED	GUIDELINES FOR QUALIFICATION OF MAINTENANCE PERSONNEL NOT FOLLOWED	IMPROPER MAINTENANCE OF SUB	IIC	2	ENSURE MAINTENANCE PERSONNEL POSSESS MINIMUM QUALIFICATIONS.	IID	2	46 CFR 157. MTS III, SECTION A.1.3.	
7.1.03A	CREW OR OPERATIONS STAFF MEMBER IS NOT QUALIFIED	NO GUIDELINES FOR QUALIFICATION OF ALL POSITIONS WITHIN CREW AND OPERATIONS STAFF	FLOODING, COLLISION, AIR CONTAMINATION, INABILITY TO SURFACE, FIRE	IC	1	FOLLOW CFR AND MTS TO DEVELOP QUALIFICATIONS FOR ALL OPERATIONS STAFF AND CREW MEMBERS.	IE	3	46 CFR 157. MTS III, SECTION A.1.3.2.	

PRELIMINARY HAZARD ANALYSIS

ELEMENT: GENERAL
SYSTEM: PEOPLE
SUBSYSTEM: QUALIFICATIONS

PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
7.1.03B	CREW OR OPERATIONS STAFF MEMBER IS NOT QUALIFIED	GUIDELINES FOR QUALIFICATION OF ALL MEMBERS OF CREW OR OPERATIONS STAFF NOT FOLLOWED	FLOODING, COLLISION, AIR CONTAMINATION, INABILITY TO SURFACE, FIRE	IB	1	FOLLOW CFR AND MTS TO DEVELOP QUALIFICATIONS FOR OPERATIONS STAFF AND CREW MEMBERS	ID	2	46 CFR 157. MTS III, SECTION A.1.3.2.	

ELEMENT: GENERAL
SYSTEM: PEOPLE
SUBSYSTEM: TRAINING

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
7.2.01A	PILOT NOT PROPERLY TRAINED IN NORMAL AND EMERGENCY PROCEDURES	NO TRAINING PROGRAM FOR PILOTS	FLOODING, COLLISION, AIR CONTAMINATION, INABILITY TO SURFACE, FIRE	IIC	2	ESTABLISH TRAINING PROGRAM TO INCLUDE CFR, MTS, AND DSPA TO DEVELOP TRAINING PROGRAM FOR PILOTS.	IIE	3	46 CFR 157. MTS I, SECTION I.1.0, MTS II, SECTION D.1.0. DSPA, SECTION I.	TIME DEPENDENT
7.2.01B	PILOT NOT PROPERLY TRAINED IN NORMAL AND EMERGENCY PROCEDURES	TRAINING PROGRAM DOCUMENTATION FOR PILOTS INACCURATE OR INCOMPLETE	FLOODING, COLLISION, AIR CONTAMINATION, INABILITY TO SURFACE, FIRE	IIC	2	FOLLOW CFR, MTS, AND DSPA TO DEVELOP TRAINING PROGRAM FOR PILOTS. PROVIDE CONFIGURATION MANAGEMENT.	IID	2	46 CFR 157. MTS I, SECTION I.4.0. MTS II, SECTION D.4.0. DSPA, SECTION III. CONFIG MGMT: TBD.	TIME DEPENDENT
7.2.01C	PILOT NOT PROPERLY TRAINED IN NORMAL AND EMERGENCY PROCEDURES	TRAINING PROGRAM FOR PILOTS NOT FOLLOWED	FLOODING, COLLISION, AIR CONTAMINATION, INABILITY TO SURFACE, FIRE	IIC	2	ENSURE TRAINING PROGRAM IS FOLLOWED BY ALL PERSONNEL. USCG AUDIT TRAINING PROGRAM.	IID	2	TBD	TIME DEPENDENT
7.2.02A	PILOT INCAPACITATED, COPILOT NOT PROPERLY TRAINED IN NORMAL AND EMERGENCY PROCEDURES	NO TRAINING PROGRAM FOR COPILOTS	FLOODING, COLLISION, AIR CONTAMINATION, INABILITY TO SURFACE, FIRE	IIC	2	ESTABLISH TRAINING PROGRAM TO INCLUDE CFR AND MTS FOR COPILOTS.	IIE	3	46 CFR 157. MTS II, SECTION I.1.0	TIME DEPENDENT
7.2.02B	PILOT INCAPACITATED, COPILOT NOT PROPERLY TRAINED IN NORMAL AND EMERGENCY PROCEDURES	TRAINING PROGRAM DOCUMENTATION FOR COPILOTS INACCURATE OR INCOMPLETE	FLOODING, COLLISION, AIR CONTAMINATION, INABILITY TO SURFACE, FIRE	IIC	2	FOLLOW CFR AND MTS TO DEVELOP TRAINING PROGRAM FOR COPILOTS. PROVIDE CONFIGURATION MANAGEMENT.	IID	2	46 CFR 157. MTS II, SECTION I.4.0. CONFIG MGMT: TBD.	TIME DEPENDENT

ELEMENT: GENERAL
SYSTEM: PEOPLE
SUBSYSTEM: TRAINING

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
7.2.02C	PILOT INCAPACITATED, COPILOT NOT PROPERLY TRAINED IN NORMAL AND EMERGENCY PROCEDURES	TRAINING PROGRAM FOR COPILOTS NOT FOLLOWED	FLOODING, COLLISION, AIR CONTAMINATION, INABILITY TO SURFACE, FIRE	IIC	2	ENSURE TRAINING PROGRAM IS FOLLOWED BY ALL PERSONNEL.	IID	2	TBD	TIME DEPENDENT
7.2.03A	MAINTENANCE PERSONNEL NOT PROPERLY TRAINED IN MAINTENANCE PROCEDURES	NO TRAINING PROGRAM FOR MAINTENANCE PERSONNEL	FLOODING, COLLISION, AIR CONTAMINATION, INABILITY TO SURFACE, FIRE	IIC	2	ESTABLISH A MAINTENANCE TRAINING PROGRAM	IIE	2	46 CFR 157. MTS II, SECTION D.5.	TIME DEPENDENT
7.2.03B	MAINTENANCE PERSONNEL NOT PROPERLY TRAINED IN MAINTENANCE PROCEDURES	TRAINING PROGRAM DOCUMENTATION FOR MAINTENANCE PERSONNEL INACCURATE OR INCOMPLETE	FLOODING, COLLISION, AIR CONTAMINATION, INABILITY TO SURFACE, FIRE	IIC	2	PROVIDE CONFIGURATION MANAGEMENT.	IID	2	MTS II, SECTION D.5.	TIME DEPENDENT
7.2.03C	MAINTENANCE PERSONNEL NOT PROPERLY TRAINED IN MAINTENANCE PROCEDURES	TRAINING PROGRAM FOR MAINTENANCE PERSONNEL NOT FOLLOWED	FLOODING, COLLISION, AIR CONTAMINATION, INABILITY TO SURFACE, FIRE	IIC	2	ENSURE TRAINING PROGRAM IS FOLLOWED BY ALL PERSONNEL.	IID	2	TBD	TIME DEPENDENT
7.2.04A	SURFACE SUPPORT VESSEL CAPTAIN NOT PROPERLY TRAINED IN NORMAL AND EMERGENCY PROCEDURES	NO TRAINING PROGRAM FOR SURFACE VESSEL CAPTAINS	COLLISION	IIC	2	ESTABLISH TRAINING PROGRAM TO INCLUDE CFR FOR CAPTAIN CERTIFICATION. TRAIN CAPTAINS IN EMERGENCY PROCEDURES FOR SUB	IIE	3	CERT: 46 CFR 10. MANNING: 46 CFR 157.	

ELEMENT: GENERAL
SYSTEM: PEOPLE
SUBSYSTEM: TRAINING

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
7.2.04B	SURFACE SUPPORT VESSEL CAPTAIN NOT PROPERLY TRAINED IN NORMAL AND EMERGENCY PROCEDURES	TRAINING PROGRAM DOCUMENTATION FOR SURFACE VESSEL CAPTAINS INACCURATE OR INCOMPLETE	COLLISION	IIC	2	CONFIGURATION MANAGEMENT OF TRAINING MATERIALS	IID	2	TBD	
7.2.04C	SURFACE SUPPORT VESSEL CAPTAIN NOT PROPERLY TRAINED IN NORMAL AND EMERGENCY PROCEDURES	TRAINING PROGRAM FOR SURFACE VESSEL CAPTAINS NOT FOLLOWED	COLLISION	IIC	2	ENSURE ALL PERSONNEL FOLLOW PROPER TRAINING PROCEDURES.	IID	2	TBD	
7.2.05A	PASSENGER TAXI VESSEL CAPTAIN NOT PROPERLY TRAINED IN NORMAL AND EMERGENCY PROCEDURES	NO TRAINING PROGRAM FOR PASSENGER TAXI VESSEL CAPTAINS	COLLISION	IIC	2	ESTABLISH TRAINING PROGRAM TO INCLUDE CFR FOR CAPTAIN CERTIFICATION. TRAIN CAPTAINS IN EMERGENCY PROCEDURES FOR SUB.	IIE	3	CERT: 46 CFR 10. MANNING: 46 CFR 157.	
7.2.05B	PASSENGER TAXI VESSEL CAPTAIN NOT PROPERLY TRAINED IN NORMAL AND EMERGENCY PROCEDURES	TRAINING PROGRAM DOCUMENTATION FOR PASSENGER TAXI VESSEL CAPTAINS INACCURATE OR INCOMPLETE	COLLISION	IIC	2	PROVIDE CONFIGURATION MANAGEMENT.	IID	2	TBD	
7.2.05C	PASSENGER TAXI VESSEL CAPTAIN NOT PROPERLY TRAINED IN NORMAL AND EMERGENCY PROCEDURES	TRAINING PROGRAM FOR PASSENGER TAXI VESSEL CAPTAINS NOT FOLLOWED	COLLISION	IIC	2	ENSURE TRAINING PROGRAM FOLLOWED FOR ALL PERSONNEL.	IID	2	TBD	

ELEMENT: GENERAL
SYSTEM: PEOPLE
SUBSYSTEM: TRAINING

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
7.2.06A	SUB ATTENDANT NOT PROPERLY TRAINED IN NORMAL AND EMERGENCY PROCEDURES	NO TRAINING PROGRAM FOR ATTENDANTS	FLOODING, FIRE, PASSENGER INJURY	IIC	2	ESTABLISH TRAINING PROGRAM FOR ATTENDANTS.	IIE	3	46 CFR 157. MTS 1, SECTION I	
7.2.06B	SUB ATTENDANT NOT PROPERLY TRAINED IN NORMAL AND EMERGENCY PROCEDURES	TRAINING PROGRAM DOCUMENTATION FOR ATTENDANTS INACCURATE OR INCOMPLETE	FLOODING, FIRE, PASSENGER INJURY	IIC	2	PROVIDE CONFIGURATION MANAGEMENT.	IID	2	TBD	
7.2.06C	SUB ATTENDANT NOT PROPERLY TRAINED IN NORMAL AND EMERGENCY PROCEDURES	TRAINING PROGRAM FOR ATTENDANTS NOT FOLLOWED	FLOODING, FIRE, PASSENGER INJURY	IIC	2	ENSURE ALL PERSONNEL FOLLOW TRAINING PROGRAM.	IID	2	TBD	
7.2.07A	DIVER NOT PROPERLY TRAINED IN NORMAL AND EMERGENCY PROCEDURES	NO TRAINING PROGRAM FOR DIVERS	INABILITY TO SURFACE SUB, INJURY TO DIVER	IIC	2	PROVIDE TRAINING PROGRAM TO INCLUDE PROPER GUIDELINES FOR TRAINING PROGRAM FOR DIVERS	IIE	3	MTS 1, SECTION I	TIME DEPENDENT
7.2.07B	DIVER NOT PROPERLY TRAINED IN NORMAL AND EMERGENCY PROCEDURES	TRAINING PROGRAM DOCUMENTATION FOR DIVERS INACCURATE OR INCOMPLETE	INABILITY TO SURFACE SUB, INJURY TO DIVER	IIC	2	PROVIDE CONFIGURATION MANAGEMENT	IID	2	TBD	TIME DEPENDENT
7.2.07C	DIVER NOT PROPERLY TRAINED IN NORMAL AND EMERGENCY PROCEDURES	TRAINING PROGRAM FOR DIVERS NOT FOLLOWED	INABILITY TO SURFACE SUB, INJURY TO DIVER	IIC	2	ENSURE TRAINING PROGRAM IS FOLLOWED FOR ALL PERSONNEL.	IID	2	TBD	TIME DEPENDENT

ELEMENT: GENERAL
SYSTEM: PEOPLE
SUBSYSTEM: MANNING

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
7.3.01A	CREW MEMBER UNABLE TO PROPERLY FULFILL DUTIES	CREW MEMBER IS ILL	FLOODING, COLLISION, AIR CONTAMINATION, INABILITY TO SURFACE, FIRE	IID	2	ESTABLISH A CROSS TRAINING PROGRAM FOR CREW	IIE	3	MTS II, SECTION D.3.3.	TIME DEPENDENT
7.3.01B	CREW MEMBER UNABLE TO PROPERLY FULFILL DUTIES	CREW MEMBER IS UNTRAINED AND UNQUALIFIED (SEE ALSO 7.1 AND 7.2)	FLOODING, COLLISION, AIR CONTAMINATION, INABILITY TO SURFACE, FIRE	IIC	2	ESTABLISH CREW QUALIFICATION PROGRAM	IID	2	46 CFR 157. MTS II, SECTION D. MTS III, SECTION A.1.3.	TIME DEPENDENT
7.3.01C	CREW MEMBER UNABLE TO PROPERLY FULFILL DUTIES	TOO FEW CREW MEMBERS ON BOARD	FLOODING, COLLISION, AIR CONTAMINATION, INABILITY TO SURFACE, FIRE	IIB	1	ESTABLISH SAFE CREW REQUIREMENTS	IID	2	46 CFR 157	TIME DEPENDENT
7.3.01D	CREW MEMBER UNABLE TO PROPERLY FULFILL DUTIES	CREW MEMBER PANICS	FLOODING, COLLISION, AIR CONTAMINATION, INABILITY TO SURFACE, FIRE	IIC	2	PSYCHOLOGICAL SCREENING OF CREW MEMBERS	IID	2	46 CFR 157. MTS II, SECTION D.3.2.	TIME DEPENDENT
7.3.02	DIVER UNABLE TO PROPERLY FULFILL EMERGENCY DUTIES	NO DIVER PROVIDED FOR OPERATIONS	INABILITY TO SURFACE	IIC	2	PROVIDE STANDBY DIVER	IIE	3	TBD	TIME DEPENDENT
7.3.03	PILOT UNABLE TO PROPERLY FULFILL DUTIES	NO EMERGENCY BREATHING DEVICE FOR SUB'S PILOT	COLLISION, FLOODING, AIR CONTAMINATION, FIRE, INABILITY TO SURFACE	IIC	2	ENSURE PILOT IS PROVIDED WITH ADEQUATE BREATHING AND OTHER EMERGENCY MEANS TC MAINTAIN OPERATION OF SUB.	IIE	3	MTS III, SECTION C.5.2.	TIME DEPENDENT

ELEMENT: GENERAL
SYSTEM: PEOPLE
SUBSYSTEM: PASSENGERS

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
7.4.01	PASSENGER PANICS ON BOARD SUB	PASSENGER HAS CLAUSTROPHOBIA OR SIMILAR CONDITION	INJURY	IIC	2	ESTABLISH A PASSENGER INDOCTRINATION PROGRAM	IID	2	TBD	
7.4.02	PASSENGER DISCHARGES FIREARM ON BOARD SUB	PASSENGER CARRIES FIREARM ON BOARD SUB	INJURY, LEAKAGE/ FLOODING	IID	2	SCREEN PASSENGERS PRIOR TO BOARDING SUB.	IIE	3	TBD	TIME DEPENDENT
7.4.03	PASSENGER RELEASES AIR CONTAMINATE INTO CABIN	PASSENGER CARRIES ATMOSPHERIC CONTAMINANT ON BOARD SUB	AIR CONTAMINATION, ILLNESS	IID	2	SCREEN PASSENGERS PRIOR TO BOARDING SUB.	IIE	3	TBD	TIME DEPENDENT
7.4.04	PASSENGER RELEASES TOXIC CONTAMINATE INTO CABIN	PASSENGER CARRIES TOXIC CONTAMINATE ON BOARD SUB	AIR CONTAMINATION, INJURY, DEATH	IID	2	SCREEN PASSENGERS PRIOR TO BOARDING SUB.	IIE	3	TBD	TIME DEPENDENT
7.4.05	FIRE IN CABIN	PASSENGER CARRIES FLAMMABLE SUBSTANCE ON BOARD SUB	DEATH, INJURY	IC	1	SCREEN PASSENGERS PRIOR TO BOARDING SUB.	ID	2	TBD	
7.4.06	PASSENGER SLIPS OR SNAGS SHOE	PASSENGER WEARS IMPROPER SHOES ON BOARD SUB	INJURY DUE TO FALL	IIB	1	REQUIRE PROPER FOOT WEAR FOR PASSENGERS.	IID	2	TBD	
7.4.07	PASSENGER SUFFERS SMOKE INHALATION DURING FIRE	FIRE IN CABIN	ILLNESS	IIC	1	SUPPLY EMERGENCY BREATHING APPARATUS. PROVIDE EMERGENCY AIR BREATHING APPARATUS FOR PASSENGERS AND CREW.	IID	2	MTS III, SECTION C.5.2.	

ELEMENT: GENERAL
SYSTEM: PEOPLE
SUBSYSTEM: PASSENGERS

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
7.4.08	PASSENGER AFFECTS OR OPERATES CONTROLS OR DISTURBS PILOT	NO PHYSICAL SEPARATION OF PILOT'S COMPARTMENT AND PILOT FROM PASSENGERS	INABILITY TO SURFACE, COLLISION	IIC	1	REQUIRE PHYSICAL SEPARATION BETWEEN PILOT AND PILOT'S COMPARTMENT AND PASSENGERS.	IIE	3	USCG, MAY 87, P.2.	TIME DEPENDENT
7.4.09	PASSENGER REQUIRES IMMEDIATE MEDICAL ATTENTION	PASSENGER HAS HEART ATTACK, STROKE, GOES INTO SHOCK, ETC.	DEATH	IC	1	ASSURE AT LEAST ONE CREW MEMBER HAS EMERGENCY MEDICAL TRAINING. REQUIRE CPR TRAINING FOR CREW (AS PER MTS), FIRST AID KIT (AS PER MTS), ARRANGEMENTS FOR EMERGENCY MEDICAL EVACUATION	ID	2	MTS II, SECTION D.4.1.K. MTS III, SECTION A.1.3.1., SECTION C.5.1.	
7.4.10	EMERGENCY EVACUATION OF PASSENGERS FROM SUB INTO WATER	FLOODING, AIR CONTAMINATION, OR FIRE FORCES EMERGENCY EVACUATION OF PASSENGERS	DROWNING	IC	1	FOLLOW CFR TO PROVIDE LIFE PRESERVERS TO PASSENGERS AND CREW. PROVIDE EMERGENCY EVACUATION PLAN.	ID	2	46 CFR 180. USCG, MAY 87, P.3. MTS III, SECTION B.4.6.8. MTS III, SECTION C.5.1. USCG, MAY 87, P.3.	TIME DEPENDENT
7.4.11	OCCUPANTS NOT WEARING SEAT BELTS DURING EMERGENCY FREE ASCENT, UNCONTROLLED DESCENT, EVASIVE MANEUVERING, OR COLLISION	PASSENGERS FAIL TO WEAR INSTALLED SEAT BELTS	INJURY DUE TO FALL	IIB	1	ENFORCEMENT BY CREW. INFORM PASSENGERS OF SAFETY PROCEDURES.	IID	2	TBD	

ELEMENT: GENERAL
SYSTEM: ENVIRONMENT
SUBSYSTEM: WEATHER

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
8.1.01A	GANGWAY BETWEEN SUB AND PASSENGER TAXI VESSEL IS UNSTABLE AND SLICK	INCLEMENT WEATHER RAISES SEA STATE, ROCKING SUB AND PASSENGER TAXI VESSEL	DROWNING, INJURY DUE TO FALL	IC	1	RESTRICT OPERATIONS TO NO GREATER THAN SEA STATE 3. MONITOR WEATHER CONTINUOUSLY.	ID	2	MTS II, SECTION E.2, WEATHER: TBD.	TIME DEPENDENT
8.1.01B	SUB BECOMES UNSTABLE WITH PASSENGERS ON DECK	INCLEMENT WEATHER RAISES SEA STATE, ROCKING SUB	DROWNING, INJURY DUE TO FALL	IC	1	RESTRICT OPERATIONS TO NO GREATER THAN SEA STATE 3. MONITOR WEATHER CONTINUOUSLY.	IE	3	MTS II, SECTION E.2. WEATHER: TBD.	TIME DEPENDENT
8.1.02	WAVES WASH ONTO DECK AND/OR DOWN HATCH	INCLEMENT WEATHER RAISES SEA STATE	DROWNING, INJURY DUE TO FALL	IC	1	STRICT CONTROL OVER OPERATING CONDITIONS. RESTRICT OPERATIONS TO NO GREATER THAN SEA STATE 3. MONITOR WEATHER CONTINOUSLY	ID	2	MTS II, SECTION E.2. WEATHER: TBD.	TIME DEPENDENT
8.1.03	LOSS OF CONTROL OF SURFACED SUB	INCLEMENT WEATHER RAISES SEA STATE	COLLISION	IIC	2	STRICT CONTROL OVER OPERATING CONDITIONS. RESTRICT OPERATIONS TO NO GREATER THAN SEA STATE 3. MONITOR WEATHER CONTINOUSLY	IID	2	MTS II. SECTION E.2. WEATHER: TBD.	

ELEMENT: GENERAL
SYSTEM: ENVIRONMENT
SUBSYSTEM: WEATHER

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
8.1.04	FAILURE OF TOW LINE OR RING DURING TOW-IN OF SUB	INCLEMENT WEATHER RAISES SEA STATE	COLLISION	IIC	2	STRICT CONTROL OVER OPERATING CONDITIONS. RESTRICT OPERATIONS TO NO GREATER THAN SEA STATE 3. MONITOR WEATHER CONTINOUSLY. ENSURE TOWLINE IS OF ADEQUATE STRENGTH.	IID	2	MTS I, SECTION G.8.1. MTS II, SECTION E.2. WEATHER: TBD	
8.1.05	LOSS OF VISIBILITY FOR SUBMARINE OR SURFACE VESSELS	DARKNESS, FOG, OR INCLEMENT WEATHER	COLLISION	IIC	2	STRICT CONTROL OVER OPERATING CONDITIONS. PROVIDE NIGHTTIME AND EMERGENCY LIGHTING FOR OPERATIONS DURING DARKNESS.	IID	2	MTS II, SECTION E.2. LIGHTS: TBD.	

ELEMENT: GENERAL
SYSTEM: ENVIRONMENT
SUBSYSTEM: SEA DYNAMICS

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
8.2.01A	LOSS OF CONTROL OF SUBMERGED SUB	OPERATING SUB IN AREA OF SUBSEA CURRENTS EQUAL TO OR GREATER THAN SPEED OF SUB	COLLISION	IIC	2	ASSURE ADEQUATE POWER TO OVERCOME CURRENTS. RESTRICT OPERATIONS TO AREAS WITH SPECIFIED SLOW CURRENTS.	IID	2	MTS II, SECTIONS E.3 AND E.4.2. 46 CFR 160, 176	
8.2.01B	LOSS OF CONTROL OF SUBMERGED SUB	OPERATING SUB IN AREA OF FRESH WATER SEEPAGE INTO MORE BUOYANT SALT WATER	COLLISION	IIC	2	ENSURE SAFE OPERATING AREA.	IID	2	46 CFR 176. MTS II, SECTIONS E.3 AND E.4.2.	
8.2.01C	LOSS OF CONTROL OF SUBMERGED SUB	OPERATING SUB IN AREA DURING SEDIMENT SLIDE	COLLISION, INABILITY TO SURFACE	IIC	2	ENSURE SAFE OPERATING AREA.	IID	2	46 CFR 176. MTS II, SECTIONS E.3 AND E.4.2.	TIME DEPENDENT
8.2.01D	LOSS OF CONTROL OF SUBMERGED SUB	OPERATING SUB THROUGH THERMAL LAYERS OR AREAS OF CHANGING TEMPERATURE	COLLISION, INABILITY TO SURFACE	IID	2	ENSURE SAFE OPERATING AREA.	IID	2	46 CFR 176. MTS II, SECTIONS E.3 AND E.4.2.	TIME DEPENDENT
8.2.01E	LOSS OF CONTROL OF SUBMERGED SUB	OPERATING IN AREA OF SALT WATER SEEPAGE INTO LESS BUOYANT FRESH WATER	COLLISION, INABILITY TO SURFACE	IIC	2	ENSURE SAFE OPERATING AREA	IID	2	46 CFR 176. MTS II, SECTIONS E.3 AND E.4.2.	TIME DEPENDENT
8.2.02	LOSS OF CONTROL OF SURFACED SUB	OPERATING SUB IN AREA OF SURFACE CURRENTS EQUAL TO OR GREATER THAN SPEED OF SUB	COLLISION	IIC	2	ASSURE ADEQUATE POWER TO OVERCOME CURRENTS	IID	2	46 CFR 176. MTS II, SECTION E.3 AND E.4.2.	
8.2.03	LOSS OF VISIBILITY	OPERATING SUB IN AREA OF TURBIDITY CURRENT	COLLISION	IID	2	ENSURE SAFE OPERATING AREA.	IIE	2	46 CFR 176. MTS II, SECTIONS E.3 AND E.4.2.	

ELEMENT: GENERAL
SYSTEM: ENVIRONMENT
SUBSYSTEM: SEA DYNAMICS

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
8.2.04	SUB BECOMES UNSTABLE WHILE SUBMERGED	OPERATING SUB IN AREA OF TURBIDITY CURRENT	INJURY	IID	2	FOLLOW USCG GUIDELINES FOR STABILITY IN ALL OPERATING CONDITIONS	IIE	2	USCG STABILITY GUIDELINES	

ELEMENT: GENERAL
SYSTEM: ENVIRONMENT
SUBSYSTEM: TOPOGRAPHY

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HR12	HAZARD CONTROL REFERENCES	NOTES
8.3.01A	DESCENDING BELOW CERTIFIED DEPTHS	OPERATING SUB IN VICINITY OF STEEP SLOPE OR DROP TO BELOW SAFE DEPTHS	LEAKAGE/ FLOODING	IIC	2	ENSURE SAFE OPERATING AREA	IID	2	46 CFR 176. MTS II, SECTION E.3 AND E.4.2.	TIME DEPENDENT
8.3.01B	DESCENDING BELOW CERTIFIED DEPTHS	OPERATING SUB WHERE SEA BOTTOM IS BELOW SAFE DEPTHS	LEAKAGE/ FLOODING	IIC	2	ENSURE SAFE OPERATING AREA	IID	2	46 CFR 176. MTS II, SECTION E.3 AND E.4.2.	TIME DEPENDENT
8.3.02	GROUNDING OR COLLISION WITH SEA BOTTOM	OPERATING SUB IN NARROW GULCHES, HILLY TERRAIN	INABILITY TO SURFACE, LEAKAGE/ FLOODING	IIC	2	ENSURE SAFE OPERATING AREA. AVOID BOTTOM CONTACT	IID	2	46 CFR 176. MTS II, SECTION E.4.4.	TIME DEPENDENT

ELEMENT: GENERAL
SYSTEM: ENVIRONMENT
SUBSYSTEM: OBSTACLES

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
8.4.01A	SUB BECOMES ENTANGLED WITH OBSTACLE	OPERATING SUB TOO NEAR ABANDONED CABLES, WIRES, NETS	INABILITY TO SURFACE	IIC	2	ENSURE SAFE OPERATING AREA. PROVIDE PROPER OPERATING PROCEDURES. FOLLOW MTS TO DESIGN SUB'S ATTACHMENTS TO PERMIT BREAKAWAY OR JETTISONING ATTACHMENT. LIMIT OR PROHIBIT SUB OPERATIONS IN AREA OF OBSTACLES.	IIE	3	46 CFR 176.01.20. MTS II, SECTIONS B.13.0 AND E.4.4. OP PROC: MTS III, SECTION B.2, AND TBD.	TIME DEPENDENT
8.4.01B	SUB BECOMES ENTANGLED WITH OBSTACLE	OPERATING SUB IN AREA CONTAINING OVER-ABUNDANCE OF PLANT LIFE	INABILITY TO SURFACE	IIC	2	ENSURE SAFE OPERATING AREA. PROVIDE PROPER OPERATING PROCEDURES. FOLLOW MTS TO DESIGN SUB'S ATTACHMENTS TO PERMIT BREAKAWAY OR JETTISONING ATTACHMENT; LIMIT OR PROHIBIT SUB OPERATIONS IN AREA OF OBSTACLES.	IIE	3	46 CFR 176.01.20. MTS II,SECTIONS B.13.0 AND E.4.4. OP PROC: MTS III, SECTION B.2, AND TBD.	TIME DEPENDENT

ELEMENT: GENERAL
SYSTEM: ENVIRONMENT
SUBSYSTEM: OBSTACLES

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
8.4.01C	SUB BECOMES ENTANGLED WITH OBSTACLE	OPERATING SUB TOO NEAR APPENDAGES OF WRECK	INABILITY TO SURFACE	IIC	2	ENSURE SAFE OPERATING AREA. PROVIDE PROPER OPERATING PROCEDURES. FOLLOW MTS TO DESIGN SUB'S ATTACHMENTS TO PERMIT BREAKAWAY OR JETTISONING ATTACHMENT. LIMIT OR PROHIBIT SUB OPERATIONS IN AREA OF OBSTACLES.	IIE	3	46 CFR 176.01.20. MTS II, SECTIONS B.13.0 AND E.4.4. OP PROC: MTS III, SECTION B.2, AND TBD.	TIME DEPENDENT
8.4.02	AGGRESSIVE MARINE LIFE ATTACKS SUB	OPERATING SUB TOO NEAR AGGRESSIVE SHARK, SWORDFISH, WHALE, ETC.	LEAKAGE/ FLOODING	IIC	2	PROVIDE FOR SAFE OPERATION NEAR MARINE CREATURES.	IIE	3	MTS II, SECTION E.4.4.	TIME DEPENDENT
8.4.03	ABANDONED PRESSURIZED VESSEL EXPLODES IN VICINITY OF SUB	SUB DISTURBS ABANDONED PRESSURIZED VESSEL	LEAKAGE/ FLOODING	IID	2	ENSURE SAFE OPERATING AREA. LIMIT OR PROHIBIT SUB OPERATIONS IN AREA OF OBSTACLES.	IIE	3	MTS II, SECTION E.4.4.	TIME DEPENDENT
8.4.04	ABANDONED ORDNANCE EXPLODES IN VICINITY OF SUB	SUB DISTURBS ABANDONED EXPLOSIVE ORDNANCE	LEAKAGE/ FLOODING	IID	2	ENSURE SAFE OPERATING AREA. LIMIT OR PROHIBIT SUB OPERATIONS IN AREA OF OBSTACLES.	IIE	3	MTS II, SECTION E.4.4.	TIME DEPENDENT
8.4.05	CORROSIVE SUBSTANCE DAMAGES EXTERIOR OF SUB	DUMPING GROUND FOR CORROSIVE SUBSTANCE IN VICINITY OF SUB OPERATIONS	LEAKAGE/ FLOODING	IID	2	ENSURE SAFE OPERATING AREA. LIMIT OR PROHIBIT OPERATIONS IN AREA OF OBSTACLES.	IIE	3	MTS II, SECTION E.4.4.	TIME DEPENDENT

ELEMENT: GENERAL
SYSTEM: ENVIRONMENT
SUBSYSTEM: OBSTACLES

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
8.4.06	SECOND SUB INTERFERES WITH FIRST SUB'S OPERATIONS	TWO SUBS IN SAME OPERATING AREA	COLLISION	IIC	2	OPERATE ONLY ONE SUB IN AN AREA	IIE	3	MTS II, SECTION E.4.4.	
8.4.07	SURFACE CRAFT OR SKIERS INTERFERE WITH SUB OPERATIONS	SURFACE CRAFT IGNORES WARNINGS DENOTING SUBSURFACE OPERATIONS	COLLISION	IIC	2	SELECT REMOTE OPERATING AREAS. SURFACE SUPPORT VESSEL KEEP AREA CLEAR	IID	2	MTS II, SECTION E.4.4.	
8.4.08A	LOSS OF VISIBILITY FOR SUBMERGED SUB	DISCHARGE PIPE DISTURBS SEDIMENT IN VICINITY OF SUB OPERATIONS	COLLISION	IID	2	DESIGN SUB OPERATIONS TO PREVENT DISTURBING OF SEABED.	IIE	3	MTS II, SECTION E.4.4.	
8.4.08B	LOSS OF VISIBILITY FOR SUBMARINE	FOREIGN MATTER INTERFERES WITH PILOT'S VIEW DURING OPERATION	COLLISION	IID	2	ENSURE SAFE OPERATING AREA. PROVIDE ALTERNATE MEANS OF VIEWING OPERATING AREA.	IIE	3	MTS II, SECTION E.4.4.	
8.4.08C	LOSS OF VISIBILITY FOR SURFACE VESSEL	FOREIGN MATTER INTERFERES WITH PILOT'S VIEW DURING OPERATION	COLLISION	IID	2	ENSURE SAFE OPERATING AREA. PROVIDE ALTERNATE MEANS OF VIEWING OPERATING AREA.	IIE	3	MTS II, SECTION E.4.4.	
8.4.09	SUB BECOMES UNSTABLE WITH PASSENGERS ON DECK	LARGE WAKE/SWELL DUE TO PASSING SHIP	INJURY, DROWNING	IIC	2	STABILITY TO ALLOW DEBARKATION UNDER WORST POSSIBLE SURFACE CONDITIONS.	IIE	3	USCG, MAY 87, P.4. MTS II, SECTION E.4.4.	

ELEMENT: GENERAL
SYSTEM: ENVIRONMENT
SUBSYSTEM: CABIN INTERIOR

PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

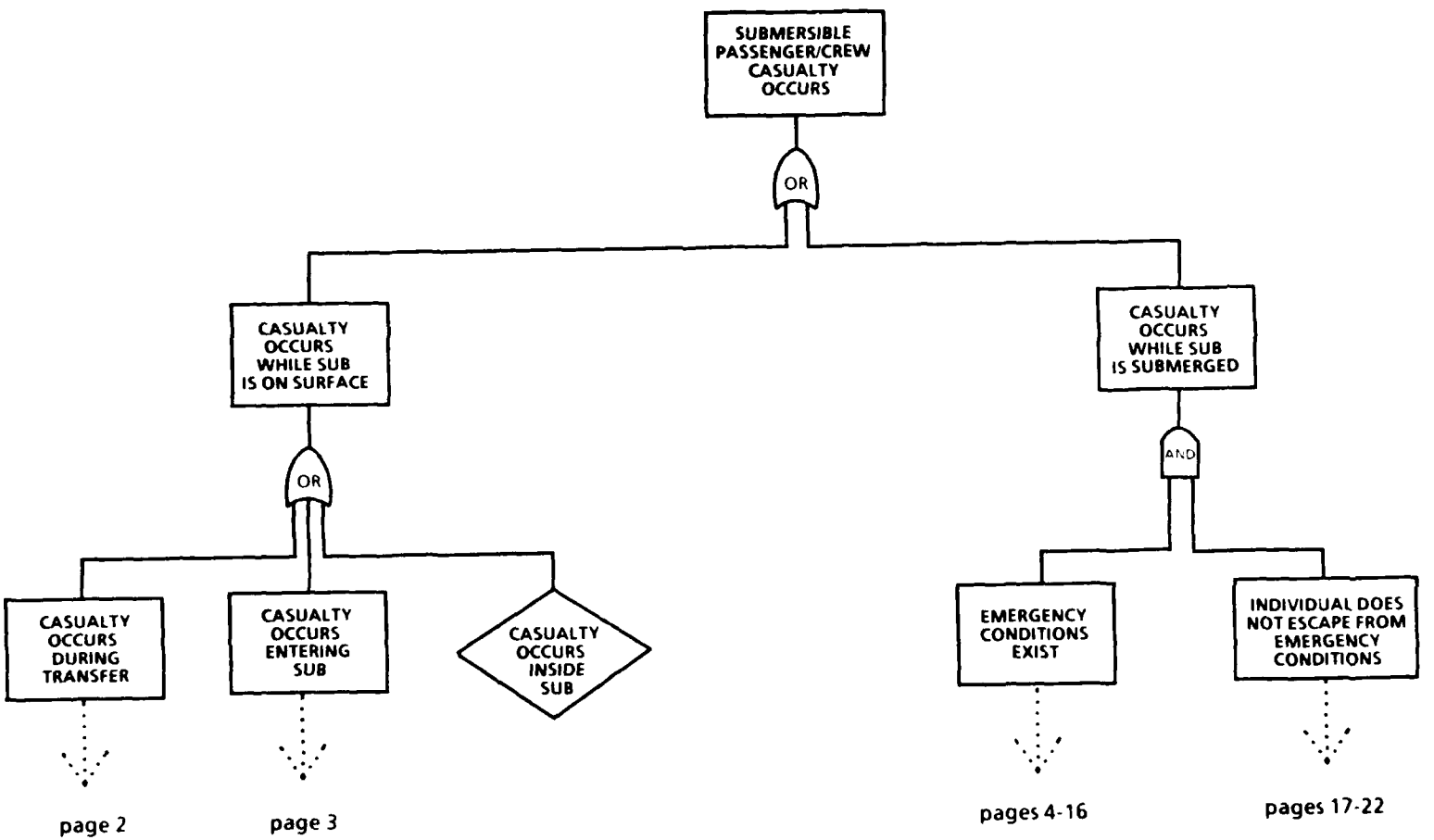
CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
8.5.01	HEATED OR BURNING CABIN MATERIALS EMIT TOXIC GASES	IMPROPER MATERIAL SELECTION FOR CABIN INTERIOR	AIR CONTAMINATION	IIC	2	FOLLOW ABS AND NAVY FOR CABIN MATERIAL SELECTION.	IID	2	ABS, SECTION 2.1. NAVMAT P-9290, SECTION B.5A.	TIME DEPENDENT
8.5.02	CABIN FLOOR IS SLICK	OCCUPANTS TRACK WATER DOWN HATCH OR SEA WASH THROUGH HATCH CAUSES WET FLOORS	INJURY DUE TO FALL	IIC	2	INSTALL NON-SKID FLOORS IN SUB.	IID	2	TBD	
8.5.03A	SHARP OBJECTS OR EDGES IN CABIN	IMPROPER DESIGN OR MATERIAL SELECTION FOR CABIN INTERIOR	INJURY	IIC	2	DESIGN REVIEW TO ELIMINATE HAZARDS. ROUND OR ELIMINATE ALL SHARPS EDGES OR OBJECTS WITHIN CABIN	IIE	3	TBD	
8.5.03B	SHARP OBJECTS OR EDGES IN CABIN	IMPROPER FABRICATION OR INSTALLATION OF CABIN INTERIOR	INJURY	IIC	2	INSPECTION DURING MANUFACTURE. FINAL WALKTHROUGH ACCEPTANCE TEST. RESOLVED THROUGH DESIGN REVIEW	IIE	3	INSPECTION: 46 CFR 176.05, 176.10, ABS, SECTION C.17. USCG, MAY 87, P.3.	
8.5.04	LOW AISLE HEIGHT FOR PASSENGERS	IMPROPER DESIGN OF CABIN INTERIOR	HEAD INJURY	IIC	2	DESIGN REVIEW TO ELIMINATE HAZARDS.	IIE	3	USCG, MAY 87, P.3.	
8.5.05A	DIFFICULT ACCESS AND EGRESS VIA LADDER THROUGH HATCH	IMPROPER DESIGN OF ACCESS HATCH OR LADDER	INJURY DUE TO FALL	IIC	2	DESIGN REVIEW TO ELIMINATE HAZARDS.	IIE	3	MTS I, SECTION G.6.1.	
8.5.05B	DIFFICULT ACCESS AND EGRESS VIA LADDER THROUGH HATCH.	WET LADDER IS SLICK	INJURY DUE TO FALL	IIC	2	NON-SKID RUNGS	IIE	3	MTS I, SECTION G.6.1.	

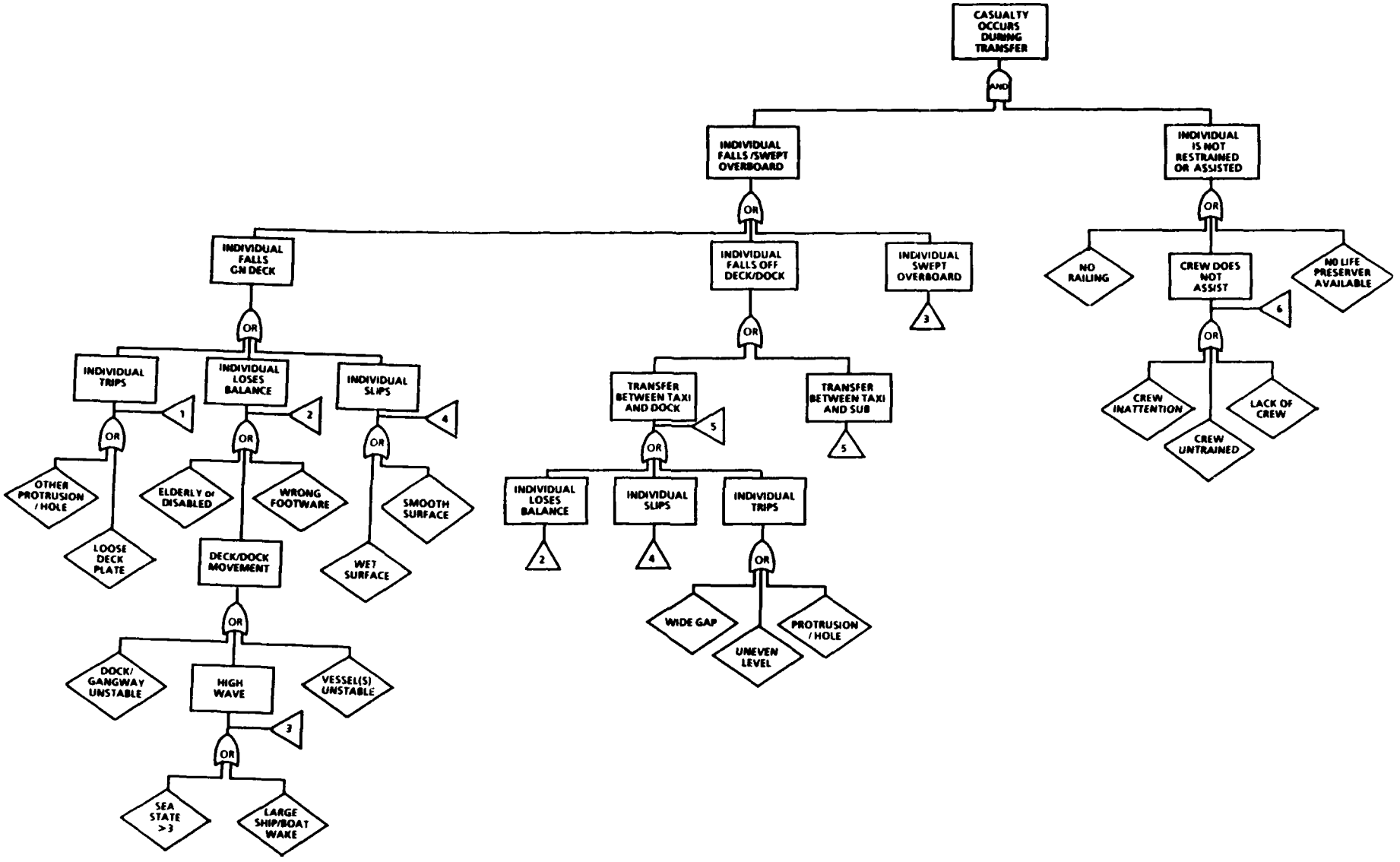
ELEMENT: GENERAL
SYSTEM: ENVIRONMENT
SUBSYSTEM: CABIN INTERIOR

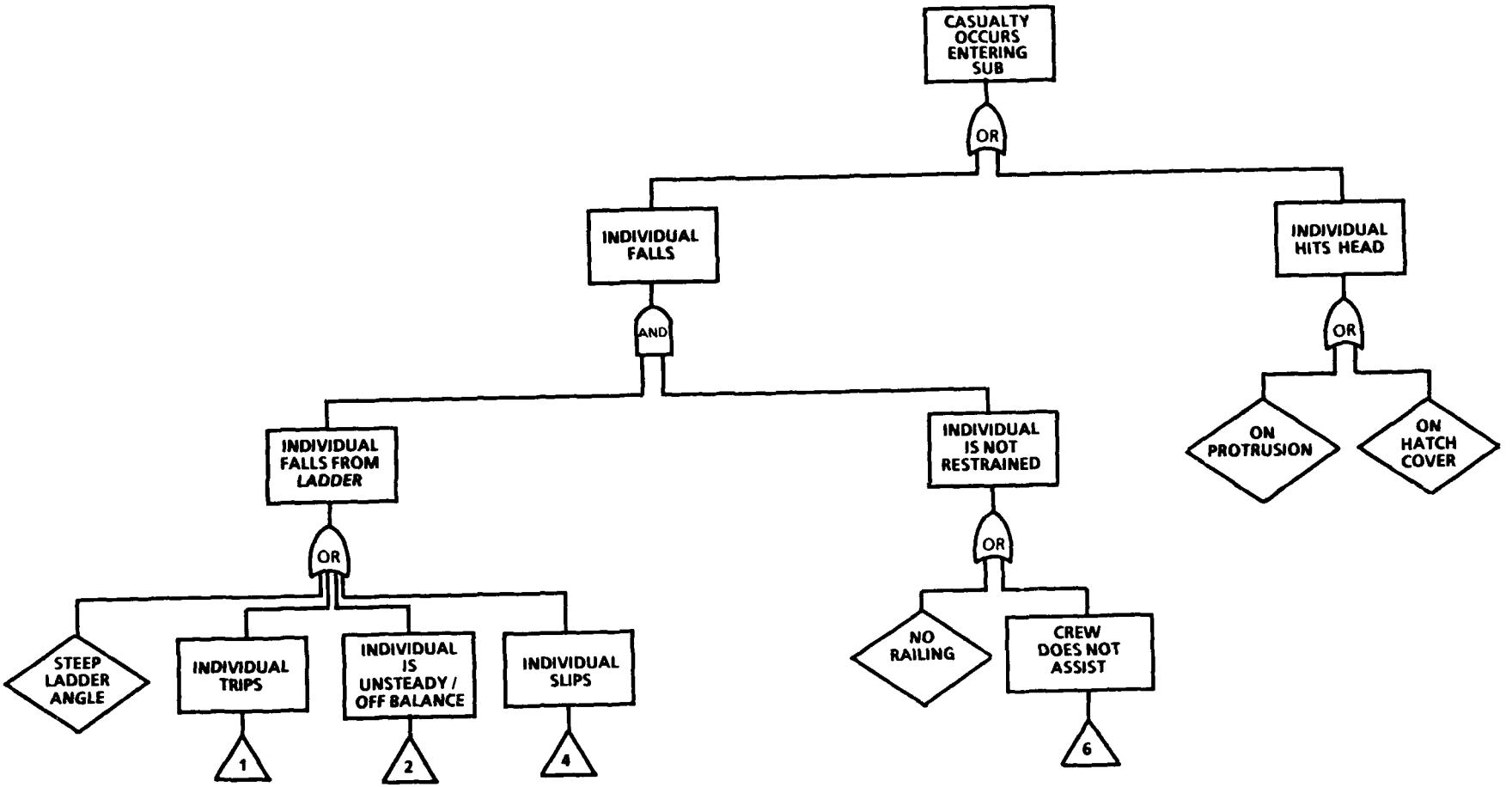
PRELIMINARY HAZARD ANALYSIS
PROJECT: PASSENGER CARRYING SUBMERSIBLE SYSTEM

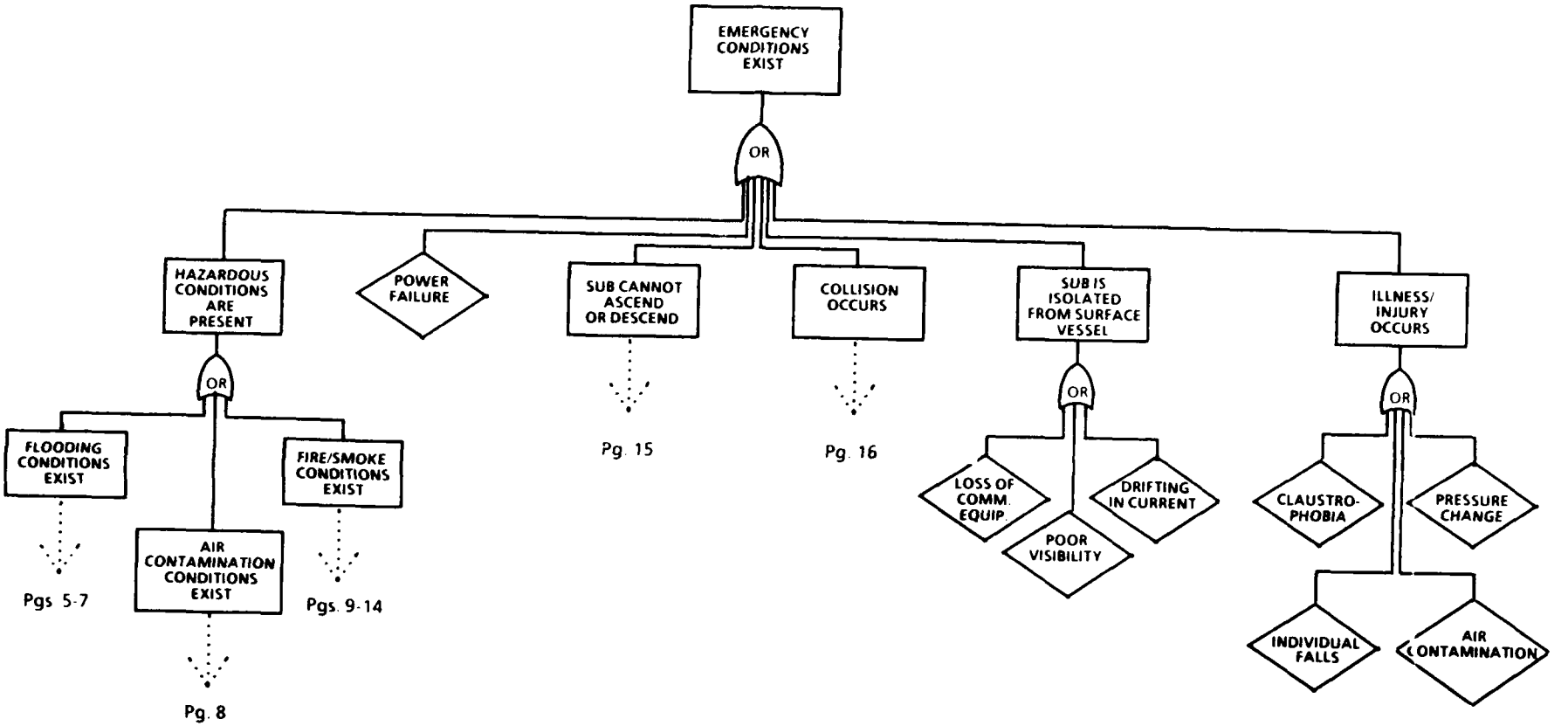
CONTROL NUMBER	HAZARD DESCRIPTION	POTENTIAL CAUSAL FACTORS	POTENTIAL EFFECTS	RISK ASSESSMENT RAC	RISK ASSESSMENT HRI	RECOMMENDATION	EFFECT OF RECOMMENDATION RAC2	EFFECT OF RECOMMENDATION HRI2	HAZARD CONTROL REFERENCES	NOTES
8.5.06	FIRE SPREADS RAPIDLY THROUGHOUT CABIN INTERIOR	IMPROPER MATERIAL SELECTION FOR CABIN INTERIOR	AIR CONTAMINATION, INJURY, DEATH	IC	2	FOLLOW CFR, ABS, AND NAVY FOR CABIN MATERIAL SELECTION.	IE	2	46 CFR 164.007-009, 164.012, 164.016, 177.10-5. ABS, SECTION 2.1 & 7.29. NAVMAT P-9290, SECTION 8.5B.	TIME DEPENDENT.

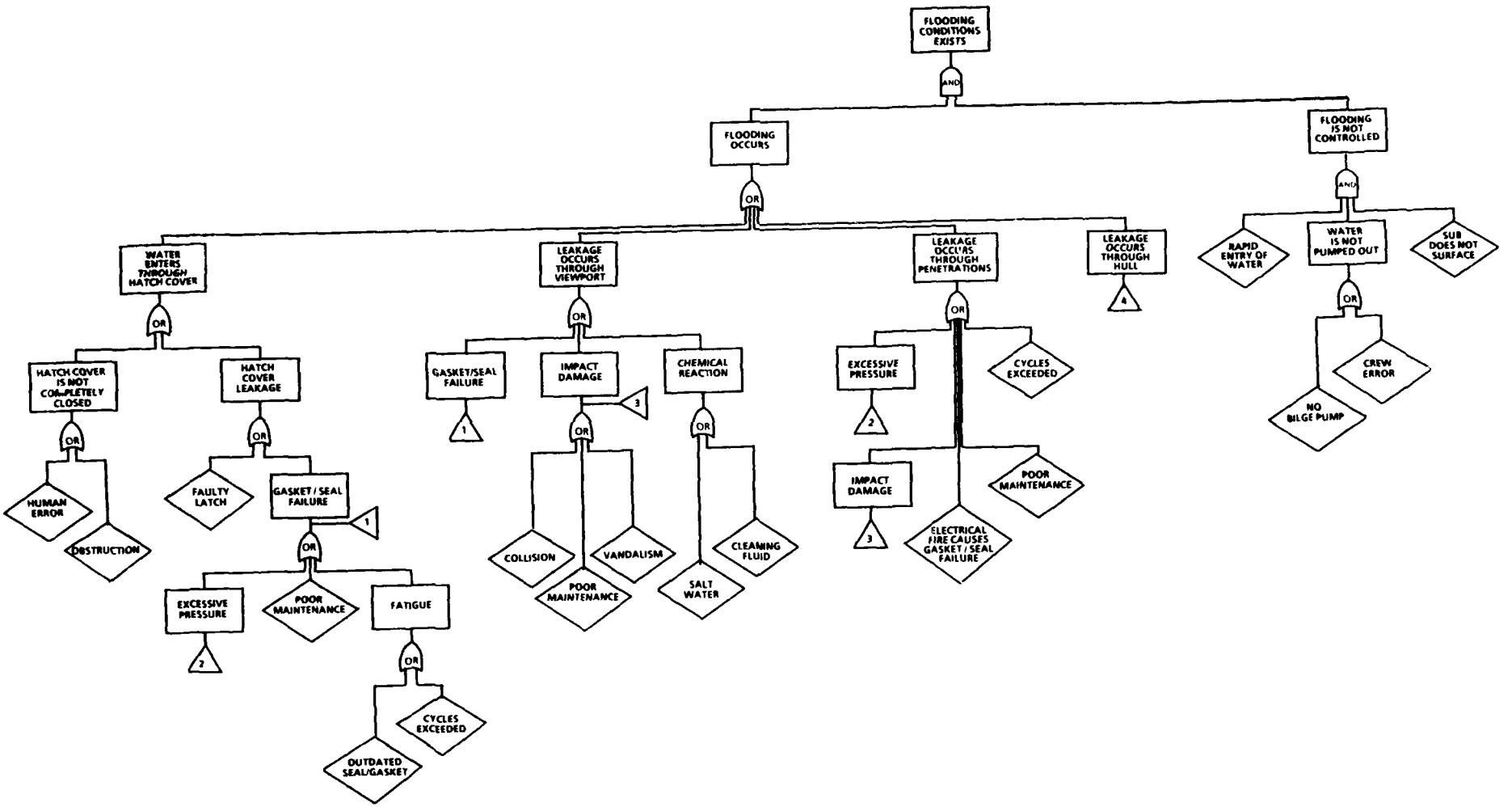
APPENDIX D. FAULT TREE DIAGRAMS

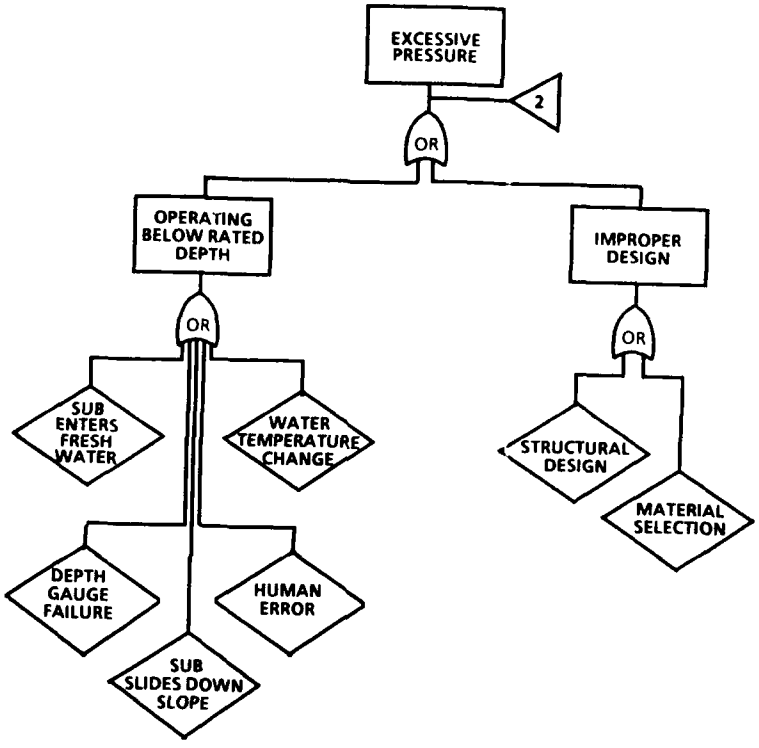


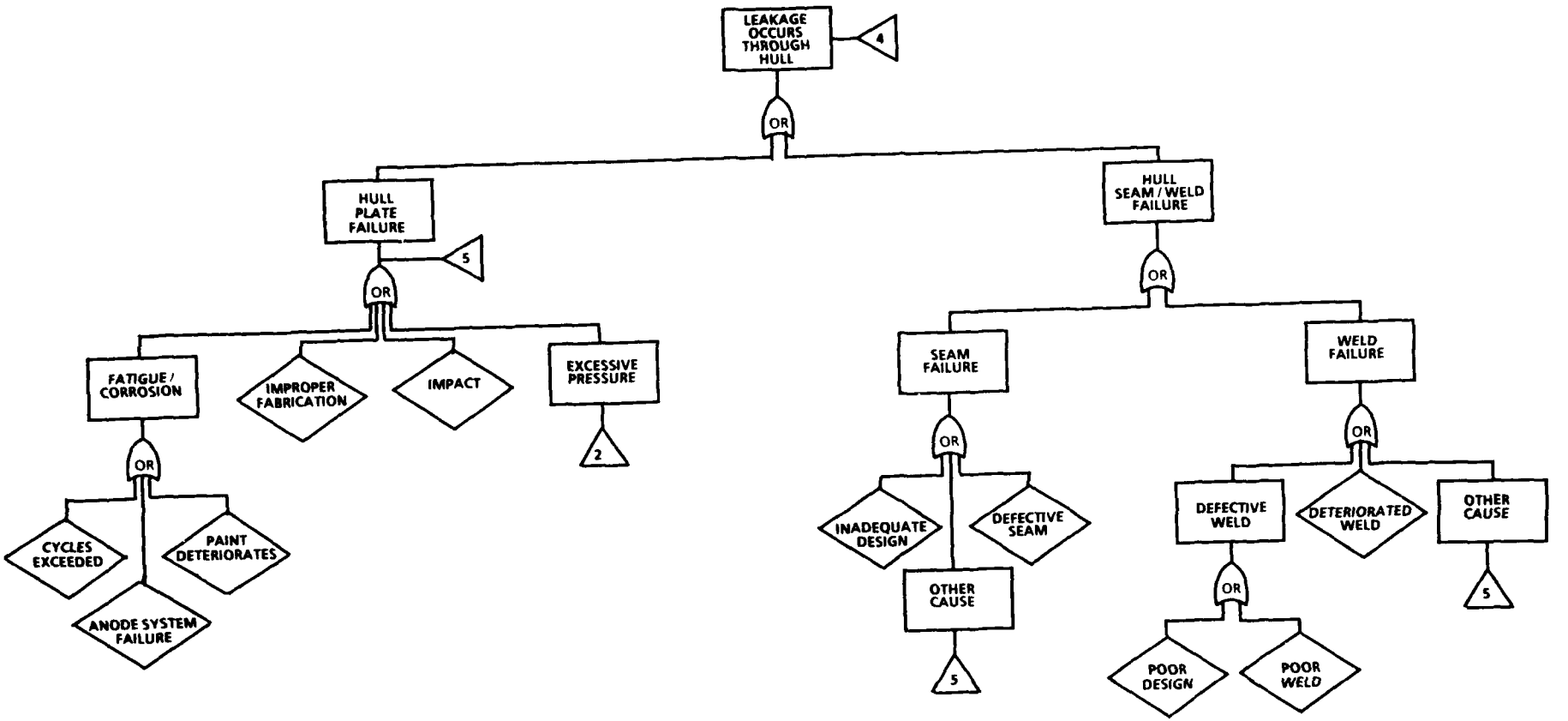

CASUALTY OCCURS DURING TRANSFER
AND
INDIVIDUAL FALLS /SWEPT OVERBOARD
INDIVIDUAL IS NOT RESTRAINED OR ASSISTED
OR
INDIVIDUAL FALLS ON DECK
INDIVIDUAL FALLS OFF DECK/DOCK
INDIVIDUAL SWEPT OVERBOARD
3
NO RAILING
CREW DOES NOT ASSIST
NO LIFE PRESERVER AVAILABLE
6
INDIVIDUAL TRIPS
INDIVIDUAL LOSES BALANCE
INDIVIDUAL SLIPS
1
2
4
TRANSFER BETWEEN TAXI AND DOCK
TRANSFER BETWEEN TAXI AND SUB
5
5
CREW INATTENTION
CREW UNTRAINED
LACK OF CREW
OTHER PROTRUSION / HOLE
LOOSE DECK PLATE
ELDERLY or DISABLED
WRONG FOOTWARE
DECK/DOCK MOVEMENT
WET SURFACE
SMOOTH SURFACE
INDIVIDUAL LOSES BALANCE
INDIVIDUAL SLIPS
INDIVIDUAL TRIPS
2
4
WIDE GAP
UNEVEN LEVEL
PROTRUSION / HOLE
DOCK/ GANGWAY UNSTABLE
HIGH WAVE
VESSEL(S) UNSTABLE
3
SEA STATE >3
LARGE SHIP/BOAT WAKE

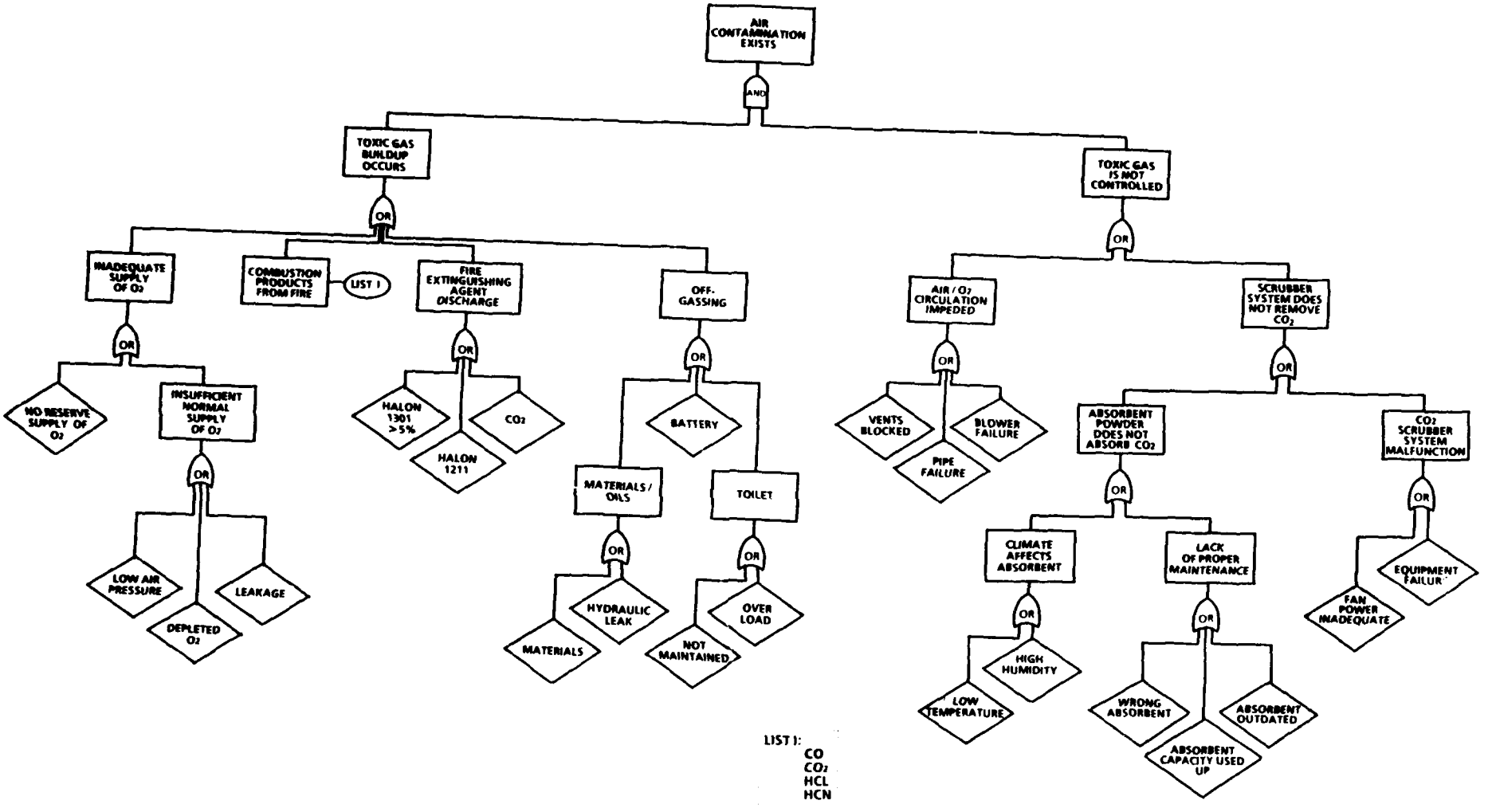

CASUALTY OCCURS ENTERING SUB
OR
INDIVIDUAL FALLS
AND
INDIVIDUAL FALLS FROM LADDER
OR
STEEP LADDER ANGLE
INDIVIDUAL TRIPS
1
INDIVIDUAL IS UNSTEADY / OFF BALANCE
2
INDIVIDUAL SLIPS
4
INDIVIDUAL IS NOT RESTRAINED
OR
NO RAILING
CREW DOES NOT ASSIST
6
INDIVIDUAL HITS HEAD
OR
ON PROTRUSION
ON HATCH COVER

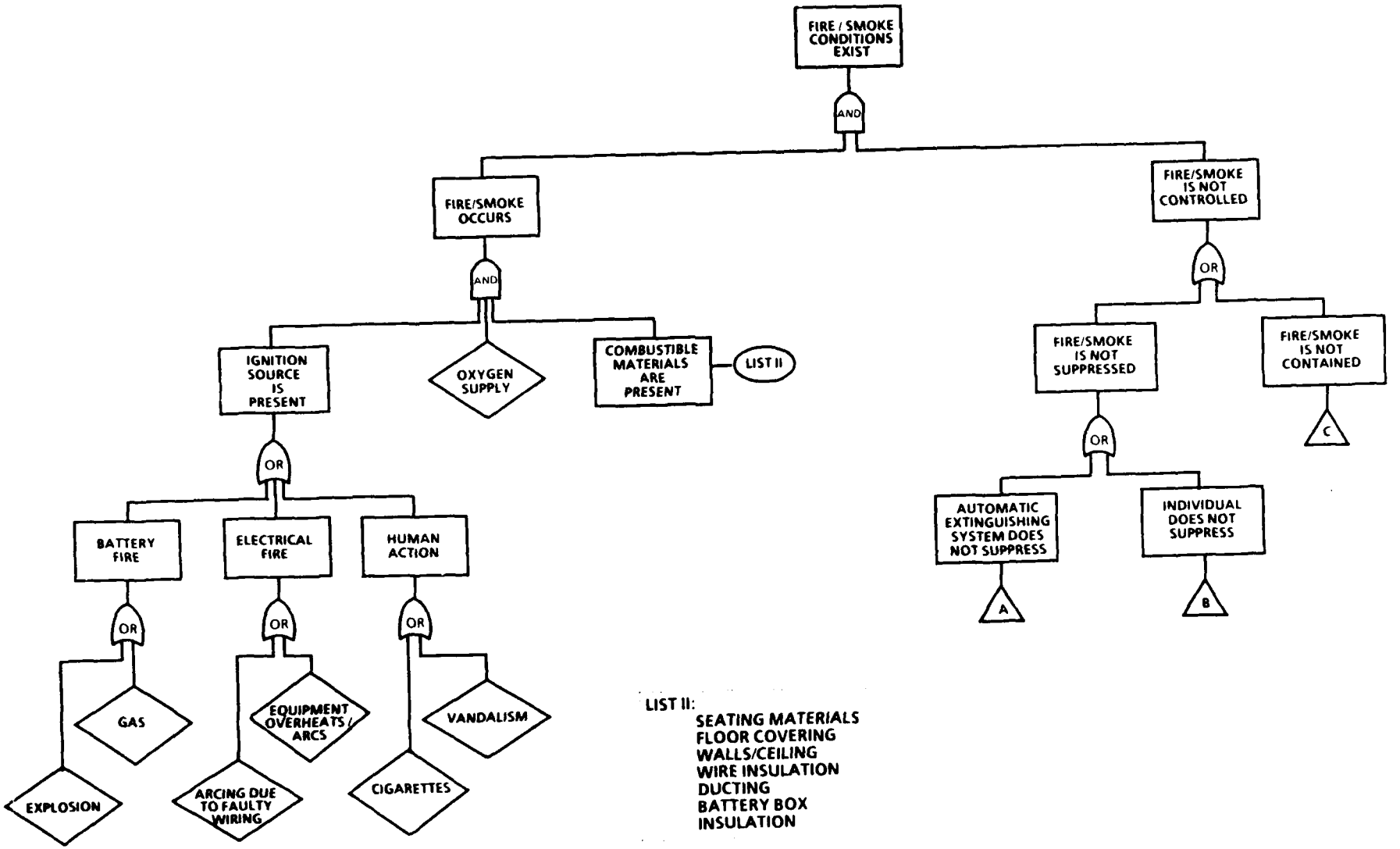

EMERGENCY CONDITIONS EXIST
OR
HAZARDOUS CONDITIONS ARE PRESENT
POWER FAILURE
SUB CANNOT ASCEND OR DESCEND
COLLISION OCCURS
SUB IS ISOLATED FROM SURFACE VESSEL
ILLNESS/ INJURY OCCURS
OR
FLOODING CONDITIONS EXIST
AIR CONTAMINATION CONDITIONS EXIST
FIRE/SMOKE CONDITIONS EXIST
Pgs 5-7
Pg. 8
Pgs. 9-14
Pg. 15
Pg. 16
OR
LOSS OF COMM. EQUIP.
DRIFTING IN CURRENT
POOR VISIBILITY
OR
CLAUSTRO-PHOBIA
PRESSURE CHANGE
INDIVIDUAL FALLS
AIR CONTAMINATION

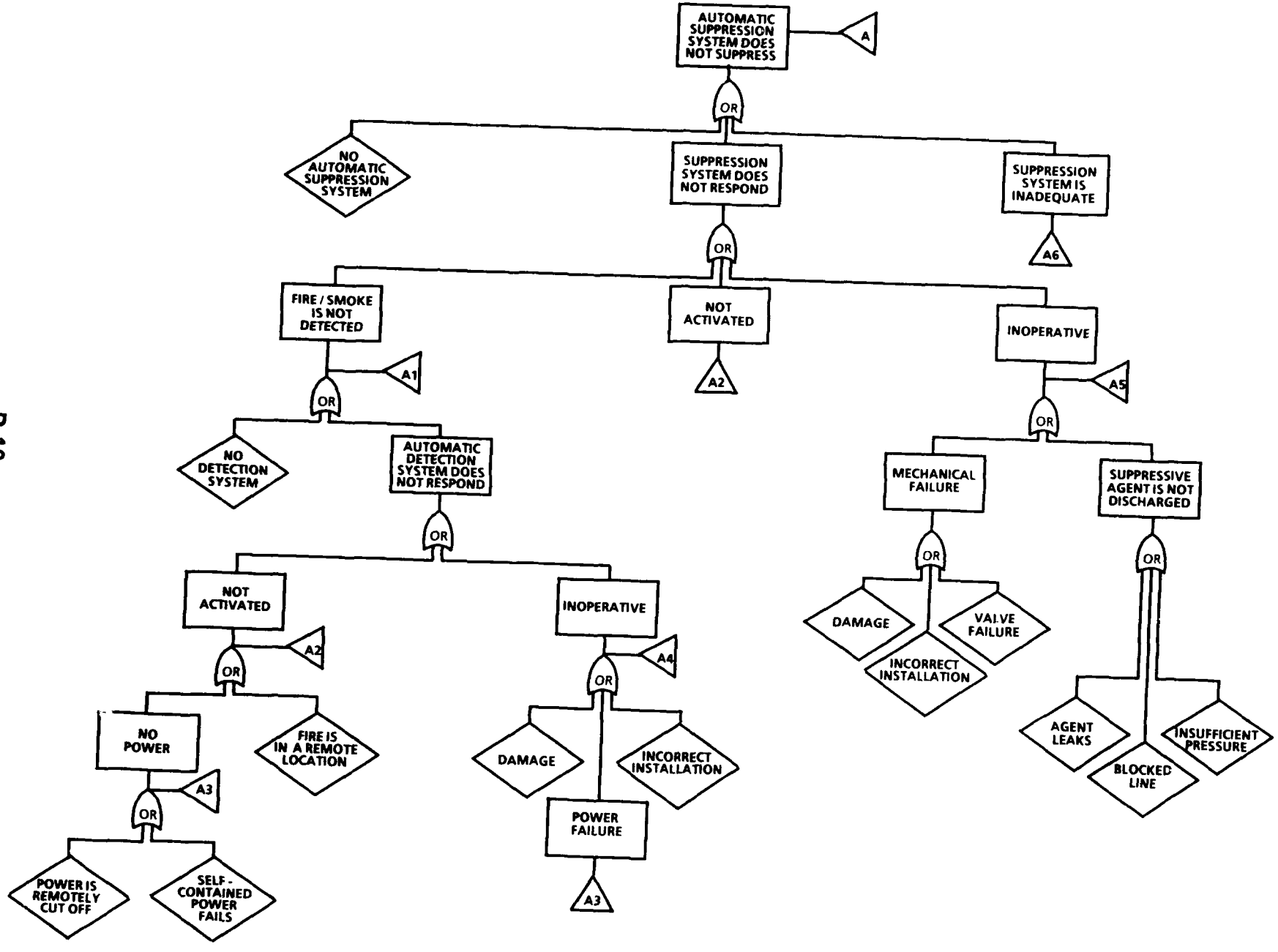

FLOODING CONDITIONS EXISTS
AND
FLOODING OCCURS
OR
FLOODING IS NOT CONTROLLED
AND
WATER ENTERS THROUGH HATCH COVER
OR
HATCH COVER IS NOT COMPLETELY CLOSED
OR
HUMAN ERROR
OBSTRUCTION
HATCH COVER LEAKAGE
OR
FAULTY LATCH
GASKET / SEAL FAILURE
1
OR
EXCESSIVE PRESSURE
2
POOR MAINTENANCE
FATIGUE
OR
CYCLES EXCEEDED
OUTDATED SEAL/GASKET
LEAKAGE OCCURS THROUGH VIEWPORT
OR
GASKET/SEAL FAILURE
1
IMPACT DAMAGE
3
OR
COLLISION
VANDALISM
POOR MAINTENANCE
CHEMICAL REACTION
OR
CLEANING FLUID
SALT WATER
LEAKAGE OCCURS THROUGH PENETRATIONS
OR
EXCESSIVE PRESSURE
2
CYCLES EXCEEDED
IMPACT DAMAGE
3
ELECTRICAL FIRE CAUSES GASKET / SEAL FAILURE
POOR MAINTENANCE
LEAKAGE OCCURS THROUGH HULL
4
RAPID ENTRY OF WATER
WATER IS NOT PUMPED OUT
OR
NO BILGE PUMP
CREW ERROR
SUB DOES NOT SURFACE

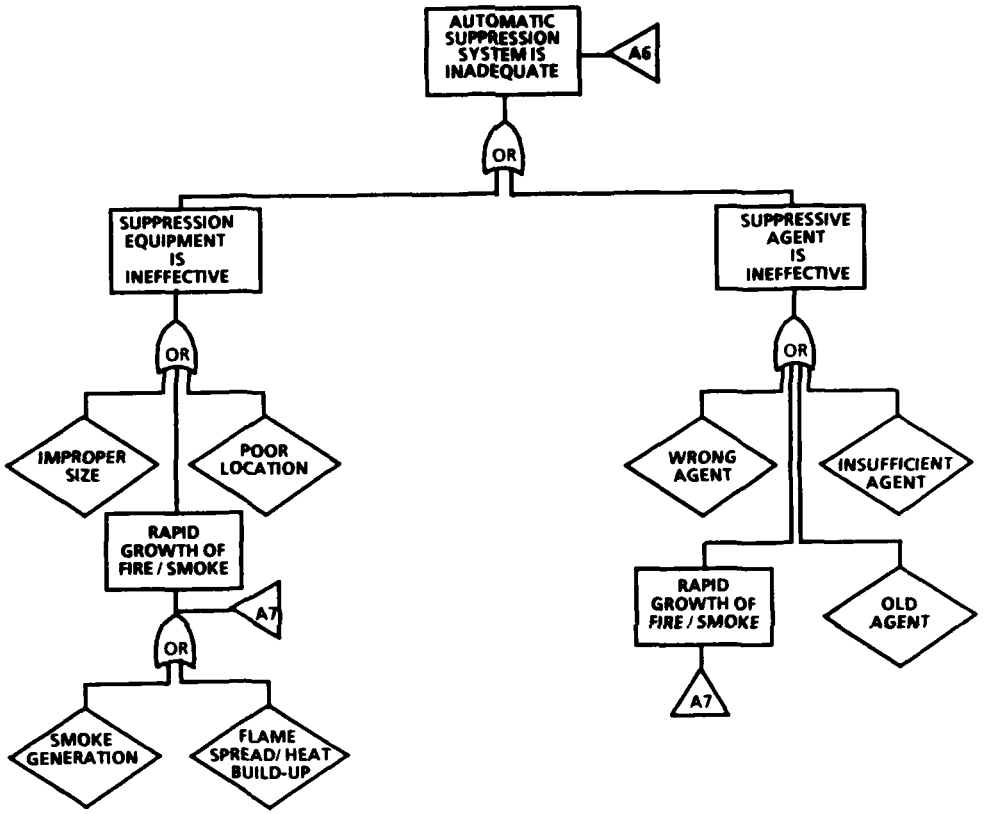

EXCESSIVE PRESSURE
2
OR
OPERATING BELOW RATED DEPTH
IMPROPER DESIGN
OR
OR
SUB ENTERS FRESH WATER
WATER TEMPERATURE CHANGE
STRUCTURAL DESIGN
MATERIAL SELECTION
DEPTH GAUGE FAILURE
HUMAN ERROR
SUB SLIDES DOWN SLOPE

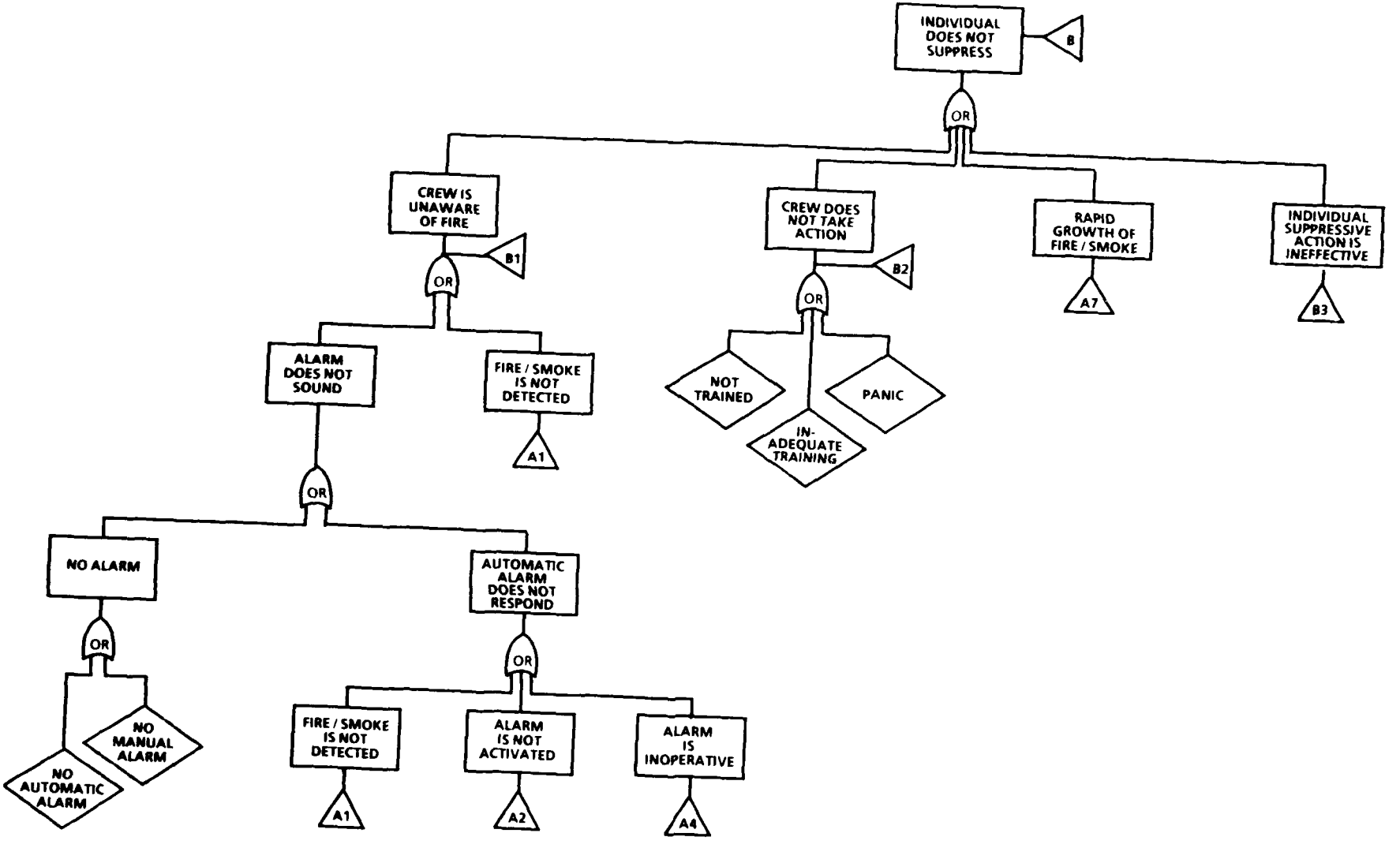

LEAKAGE OCCURS THROUGH HULL
4
OR
HULL PLATE FAILURE
5
OR
FATIGUE / CORROSION
IMPROPER FABRICATION
IMPACT
EXCESSIVE PRESSURE
2
OR
CYCLES EXCEEDED
PAINT DETERIORATES
ANODE SYSTEM FAILURE
HULL SEAM / WELD FAILURE
OR
SEAM FAILURE
WELD FAILURE
OR
INADEQUATE DESIGN
DEFECTIVE SEAM
OTHER CAUSE
5
OR
DEFECTIVE WELD
DETERIORATED WELD
OTHER CAUSE
5
OR
POOR DESIGN
POOR WELD

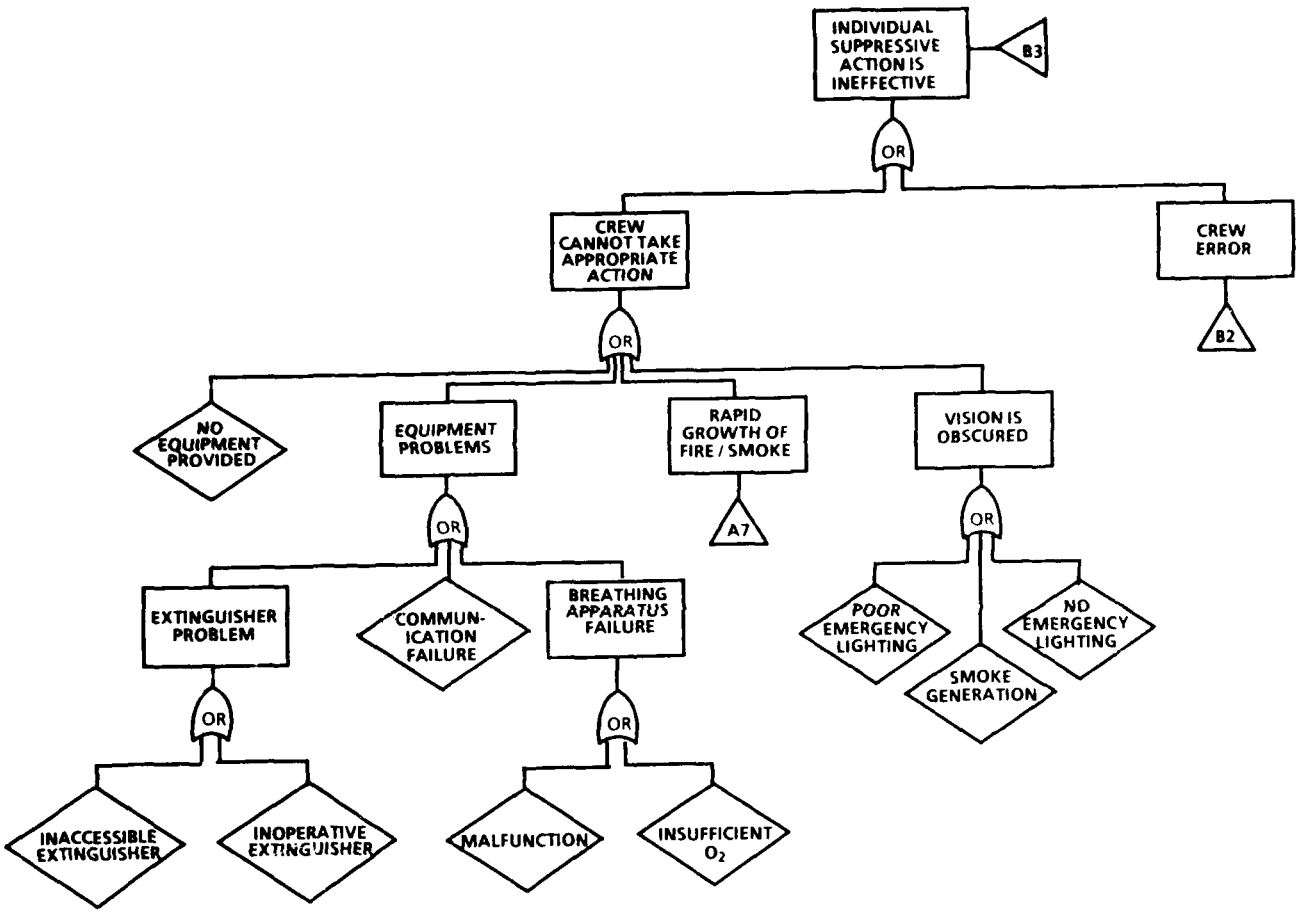

AIR CONTAMINATION EXISTS
AND
TOXIC GAS BUILDUP OCCURS
TOXIC GAS IS NOT CONTROLLED
OR
INADEQUATE SUPPLY OF O2
COMBUSTION PRODUCTS FROM FIRE
LIST 1
FIRE EXTINGUISHING AGENT DISCHARGE
OFF-GASSING
AIR / O2 CIRCULATION IMPEDED
SCRUBBER SYSTEM DOES NOT REMOVE CO2
NO RESERVE SUPPLY OF O2
INSUFFICIENT NORMAL SUPPLY OF O2
HALON 1301 >5%
CO2
HALON 1211
BATTERY
MATERIALS / OILS
TOILET
VENTS BLOCKED
BLOWER FAILURE
PIPE FAILURE
ABSORBENT POWDER DOES NOT ABSORB CO2
CO2 SCRUBBER SYSTEM MALFUNCTION
LOW AIR PRESSURE
DEPLETED O2
LEAKAGE
HYDRAULIC LEAK
MATERIALS
OVER LOAD
NOT MAINTAINED
CLIMATE AFFECTS ABSORBENT
LACK OF PROPER MAINTENANCE
EQUIPMENT FAILUR
FAN POWER INADEQUATE
HIGH HUMIDITY
LOW TEMPERATURE
WRONG ABSORBENT
ABSORBENT OUTDATED
ABSORBENT CAPACITY USED UP
LIST 1:
CO
CO2
HCL
HCN

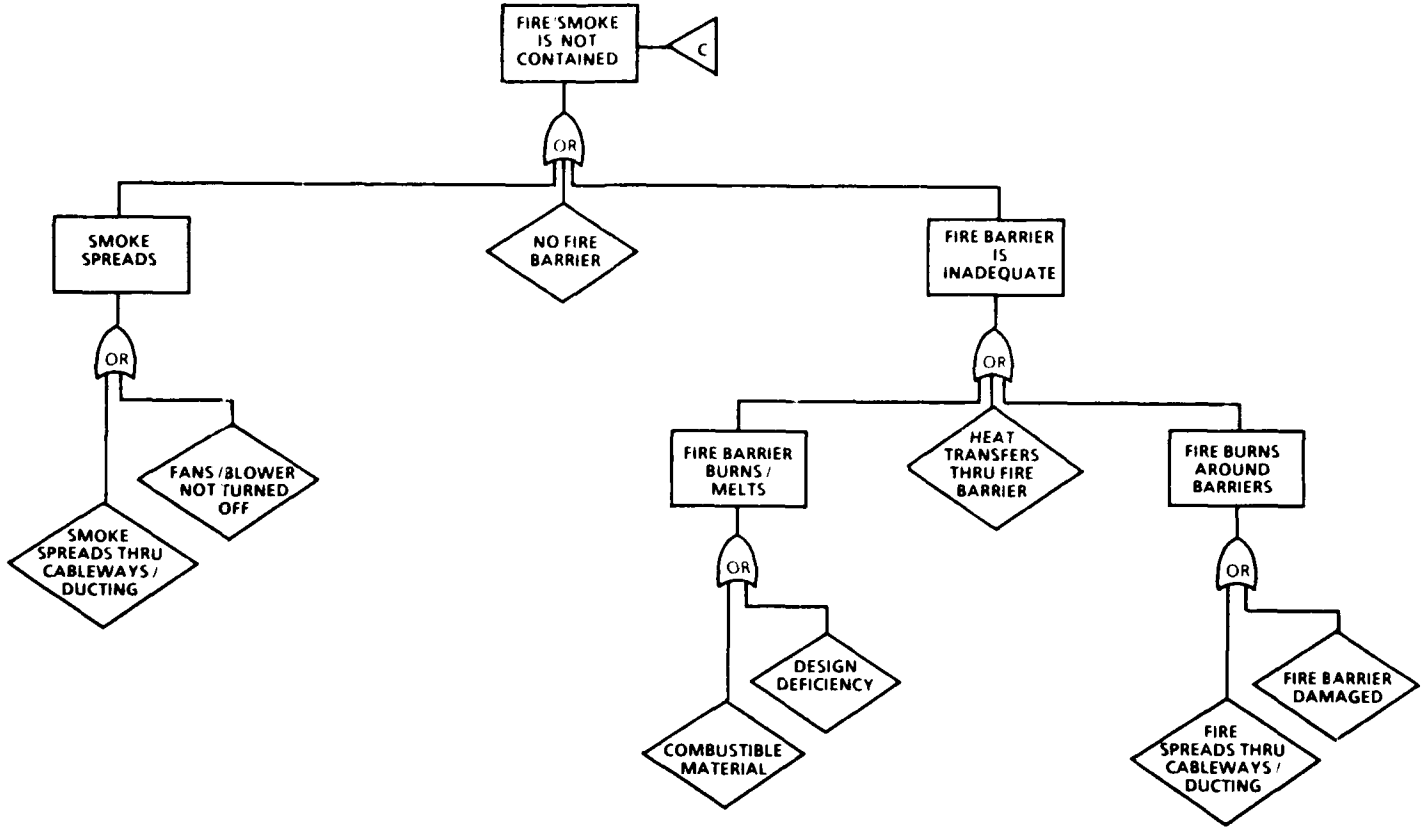

FIRE / SMOKE CONDITIONS EXIST
AND
FIRE/SMOKE OCCURS
AND
IGNITION SOURCE IS PRESENT
OXYGEN SUPPLY
COMBUSTIBLE MATERIALS ARE PRESENT
LIST II
OR
BATTERY FIRE
ELECTRICAL FIRE
HUMAN ACTION
OR
OR
OR
GAS
EXPLOSION
EQUIPMENT OVERHEATS / ARCS
ARCING DUE TO FAULTY WIRING
VANDALISM
CIGARETTES
FIRE/SMOKE IS NOT CONTROLLED
OR
FIRE/SMOKE IS NOT SUPPRESSED
FIRE/SMOKE IS NOT CONTAINED
OR
AUTOMATIC EXTINGUISHING SYSTEM DOES NOT SUPPRESS
INDIVIDUAL DOES NOT SUPPRESS
A
B
C
LIST II:
SEATING MATERIALS
FLOOR COVERING
WALLS/CEILING
WIRE INSULATION
DUCTING
BATTERY BOX
INSULATION

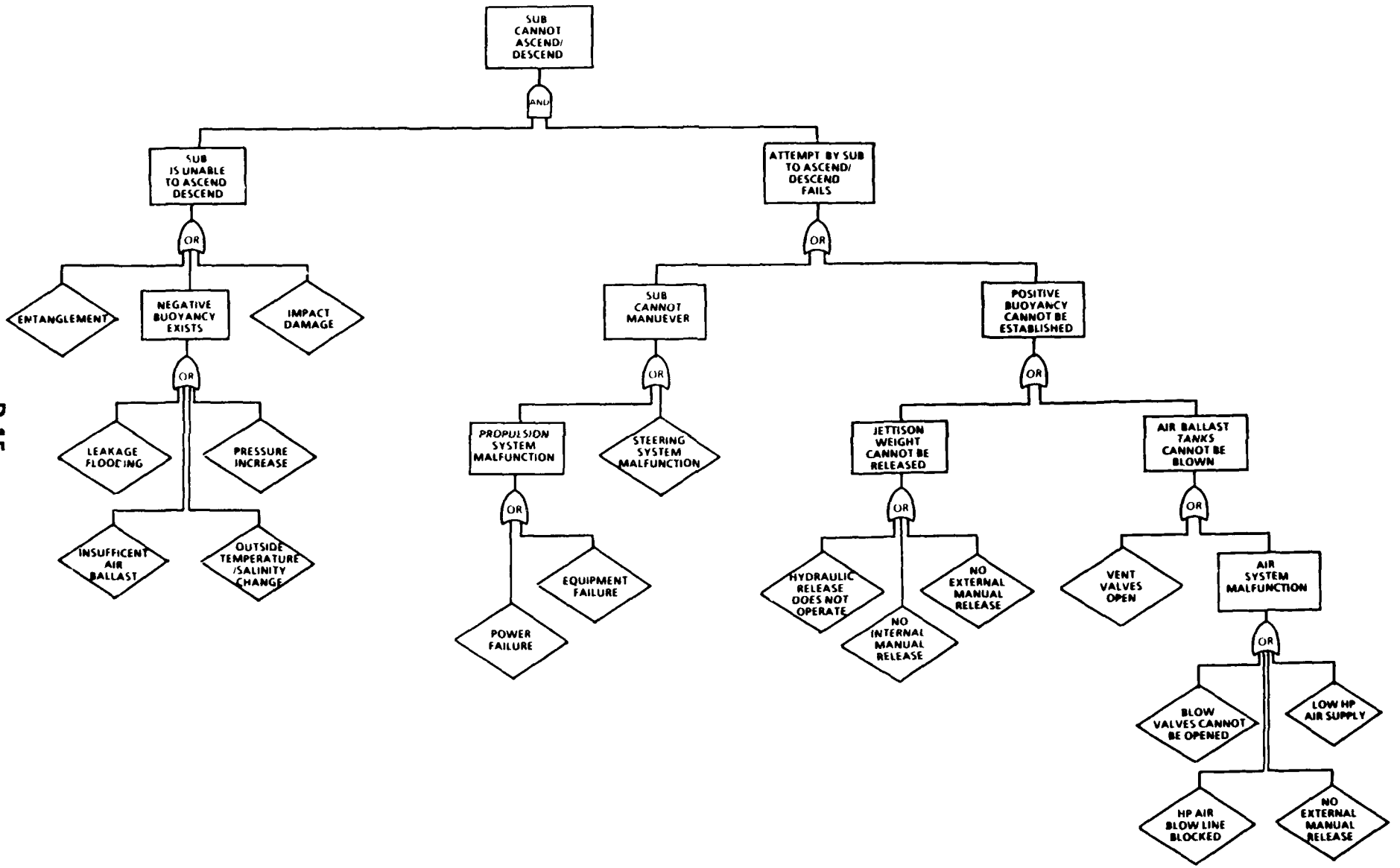

AUTOMATIC SUPPRESSION SYSTEM DOES NOT SUPPRESS
A
OR
NO AUTOMATIC SUPPRESSION SYSTEM
SUPPRESSION SYSTEM DOES NOT RESPOND
SUPPRESSION SYSTEM IS INADEQUATE
A6
OR
FIRE / SMOKE IS NOT DETECTED
NOT ACTIVATED
INOPERATIVE
A1
A2
A5
OR
NO DETECTION SYSTEM
AUTOMATIC DETECTION SYSTEM DOES NOT RESPOND
MECHANICAL FAILURE
SUPPRESSIVE AGENT IS NOT DISCHARGED
OR
OR
OR
NOT ACTIVATED
INOPERATIVE
DAMAGE
VALVE FAILURE
INCORRECT INSTALLATION
AGENT LEAKS
INSUFFICIENT PRESSURE
BLOCKED LINE
A2
A4
OR
OR
NO POWER
FIRE IS IN A REMOTE LOCATION
DAMAGE
INCORRECT INSTALLATION
A3
POWER FAILURE
OR
POWER IS REMOTELY CUT OFF
SELF - CONTAINED POWER FAILS
A3

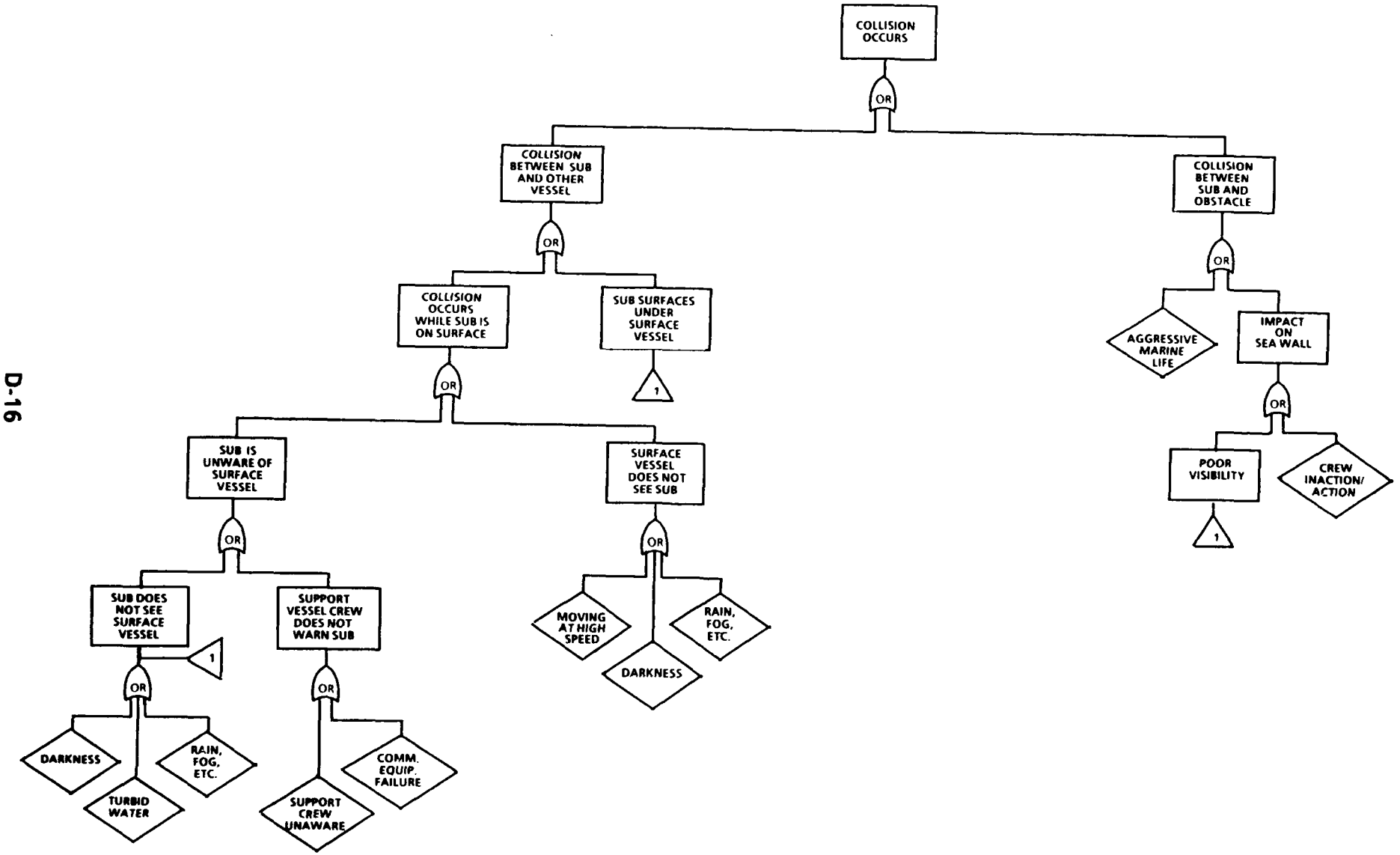

AUTOMATIC SUPPRESSION SYSTEM IS INADEQUATE
A6
OR
SUPPRESSION EQUIPMENT IS INEFFECTIVE
SUPPRESSIVE AGENT IS INEFFECTIVE
OR
OR
IMPROPER SIZE
POOR LOCATION
WRONG AGENT
INSUFFICIENT AGENT
RAPID GROWTH OF FIRE / SMOKE
A7
OR
RAPID GROWTH OF FIRE / SMOKE
OLD AGENT
SMOKE GENERATION
FLAME SPREAD/ HEAT BUILD-UP
A7

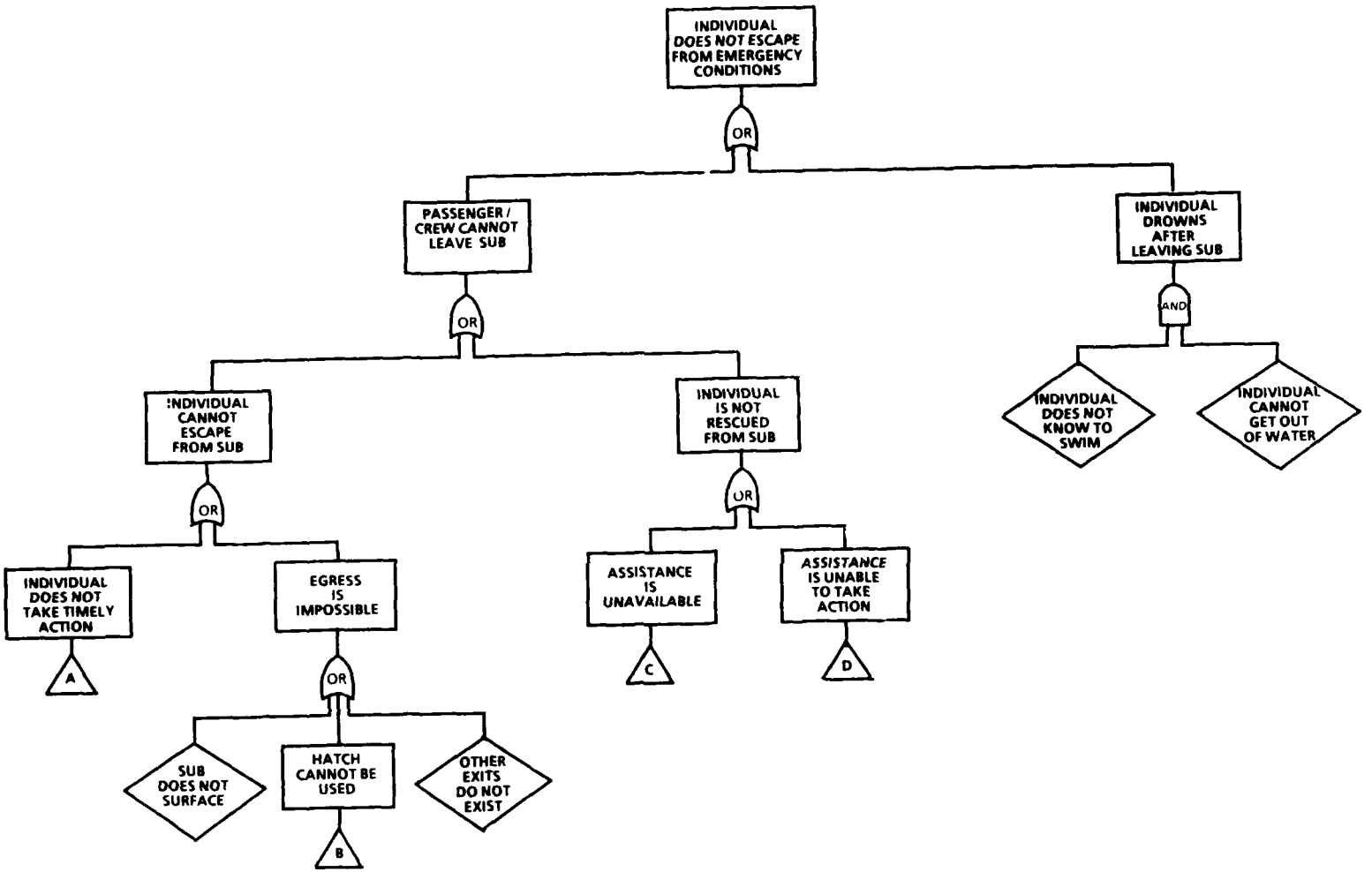

INDIVIDUAL DOES NOT SUPPRESS
B
OR
CREW IS UNAWARE OF FIRE
B1
OR
ALARM DOES NOT SOUND
FIRE / SMOKE IS NOT DETECTED
A1
OR
NO ALARM
OR
NO AUTOMATIC ALARM
NO MANUAL ALARM
AUTOMATIC ALARM DOES NOT RESPOND
OR
FIRE / SMOKE IS NOT DETECTED
A1
ALARM IS NOT ACTIVATED
A2
ALARM IS INOPERATIVE
A4
CREW DOES NOT TAKE ACTION
B2
OR
NOT TRAINED
IN-ADEQUATE TRAINING
PANIC
RAPID GROWTH OF FIRE / SMOKE
A7
INDIVIDUAL SUPPRESSIVE ACTION IS INEFFECTIVE
B3

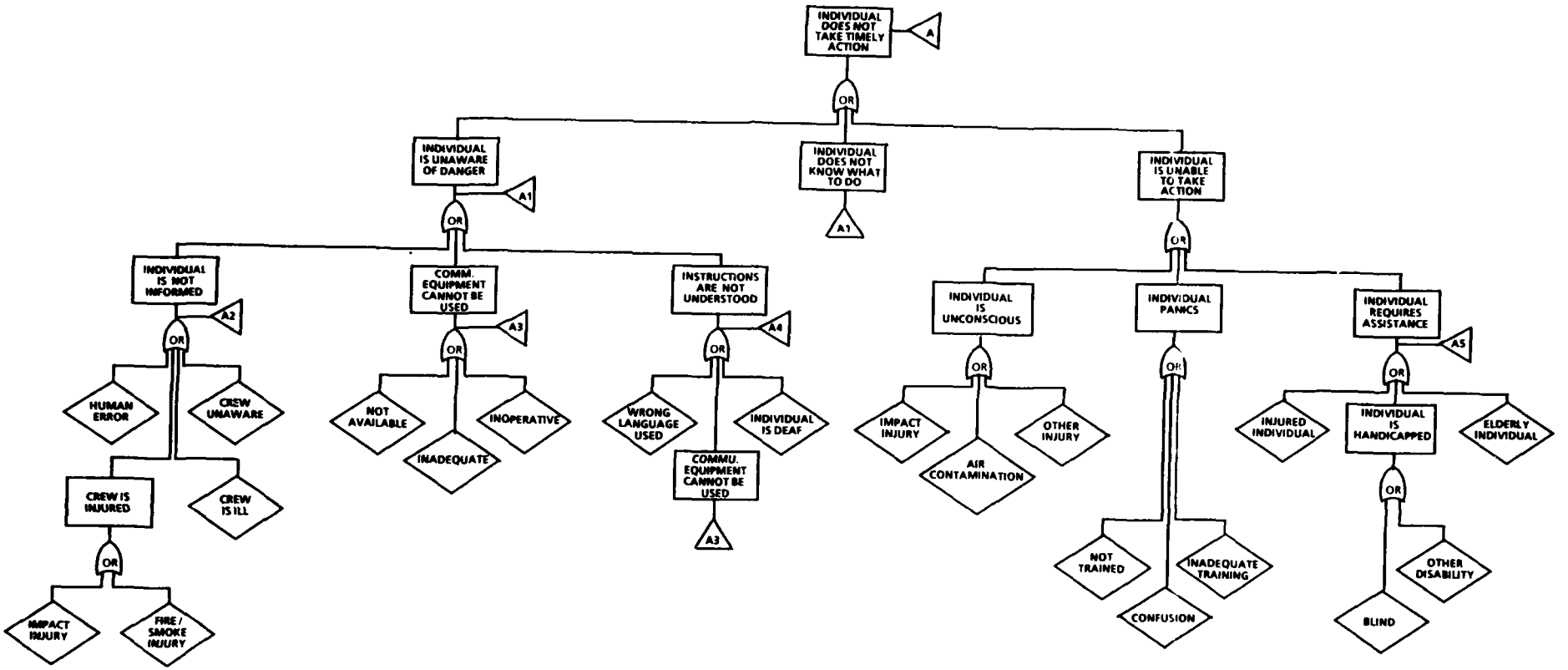

INDIVIDUAL SUPPRESSIVE ACTION IS INEFFECTIVE
B3
OR
CREW CANNOT TAKE APPROPRIATE ACTION
CREW ERROR
B2
OR
NO EQUIPMENT PROVIDED
EQUIPMENT PROBLEMS
RAPID GROWTH OF FIRE / SMOKE
VISION IS OBSCURED
A7
OR
OR
EXTINGUISHER PROBLEM
COMMUN-ICATION FAILURE
BREATHING APPARATUS FAILURE
POOR EMERGENCY LIGHTING
NO EMERGENCY LIGHTING
SMOKE GENERATION
OR
OR
INACCESSIBLE EXTINGUISHER
INOPERATIVE EXTINGUISHER
MALFUNCTION
INSUFFICIENT O_2

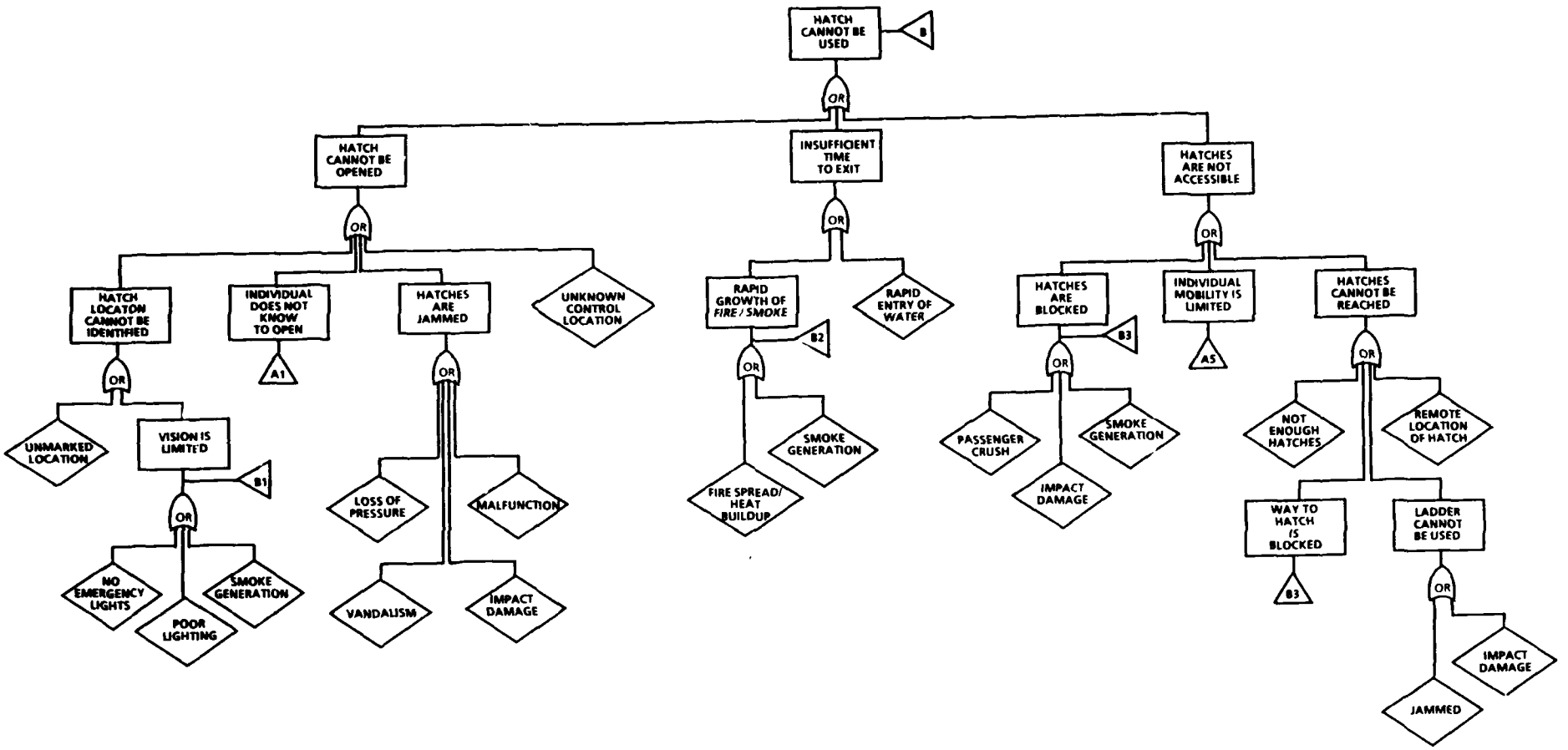

FIRE/SMOKE IS NOT CONTAINED
C
OR
SMOKE SPREADS
NO FIRE BARRIER
FIRE BARRIER IS INADEQUATE
OR
FANS/BLOWER NOT TURNED OFF
SMOKE SPREADS THRU CABLEWAYS/ DUCTING
OR
FIRE BARRIER BURNS/ MELTS
HEAT TRANSFERS THRU FIRE BARRIER
FIRE BURNS AROUND BARRIERS
OR
DESIGN DEFICIENCY
COMBUSTIBLE MATERIAL
OR
FIRE BARRIER DAMAGED
FIRE SPREADS THRU CABLEWAYS/ DUCTING

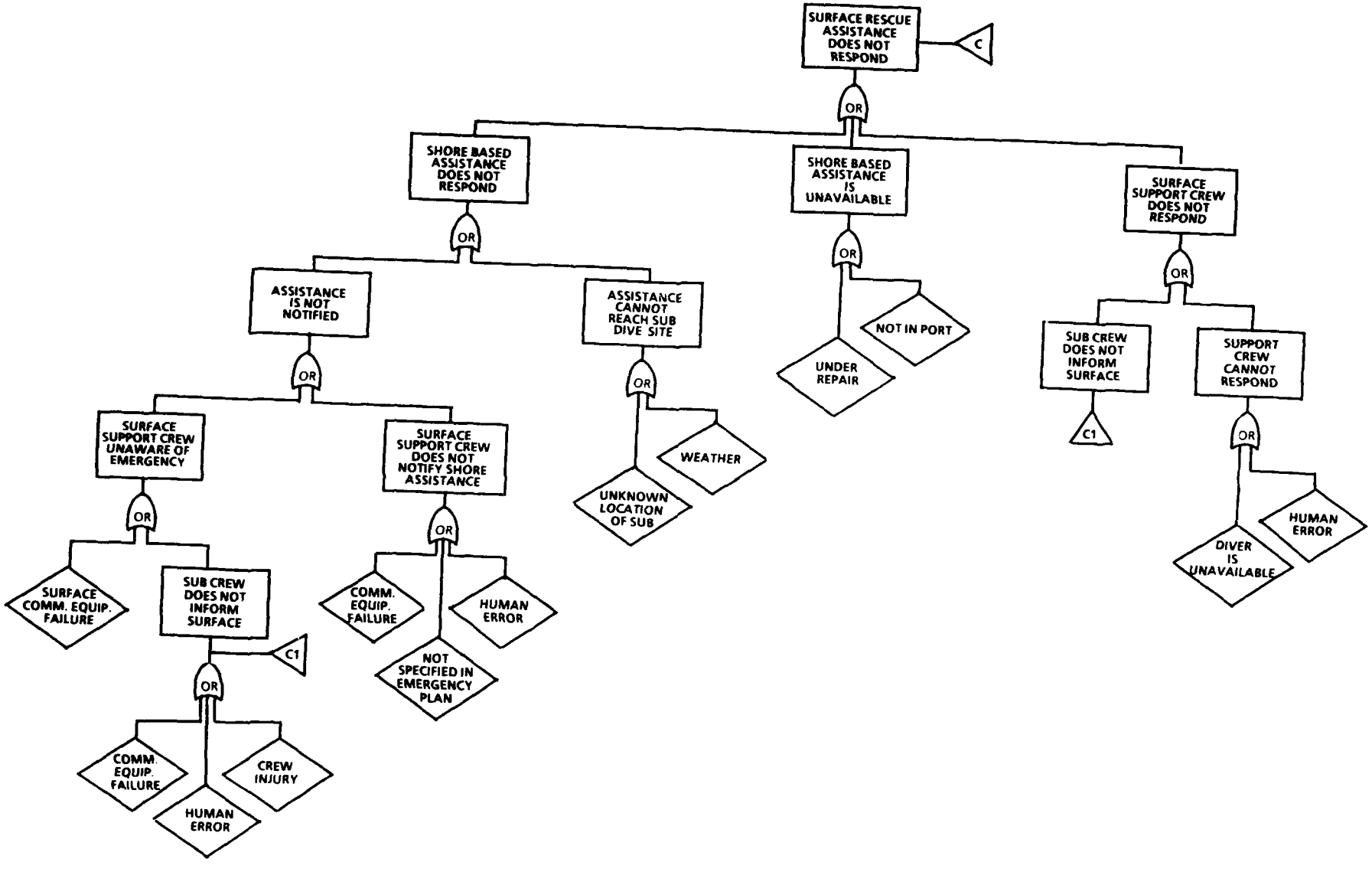

SUB CANNOT ASCEND/ DESCEND
AND
SUB IS UNABLE TO ASCEND DESCEND
ATTEMPT BY SUB TO ASCEND/ DESCEND FAILS
OR
ENTANGLEMENT
NEGATIVE BUOYANCY EXISTS
IMPACT DAMAGE
LEAKAGE FLOODING
PRESSURE INCREASE
INSUFFICENT AIR BALLAST
OUTSIDE TEMPERATURE /SALINITY CHANGE
SUB CANNOT MANUEVER
POSITIVE BUOYANCY CANNOT BE ESTABLISHED
PROPULSION SYSTEM MALFUNCTION
STEERING SYSTEM MALFUNCTION
EQUIPMENT FAILURE
POWER FAILURE
JETTISON WEIGHT CANNOT BE RELEASED
AIR BALLAST TANKS CANNOT BE BLOWN
HYDRAULIC RELEASE DOES NOT OPERATE
NO INTERNAL MANUAL RELEASE
NO EXTERNAL MANUAL RELEASE
VENT VALVES OPEN
AIR SYSTEM MALFUNCTION
BLOW VALVES CANNOT BE OPENED
LOW HP AIR SUPPLY
HP AIR BLOW LINE BLOCKED
NO EXTERNAL MANUAL RELEASE

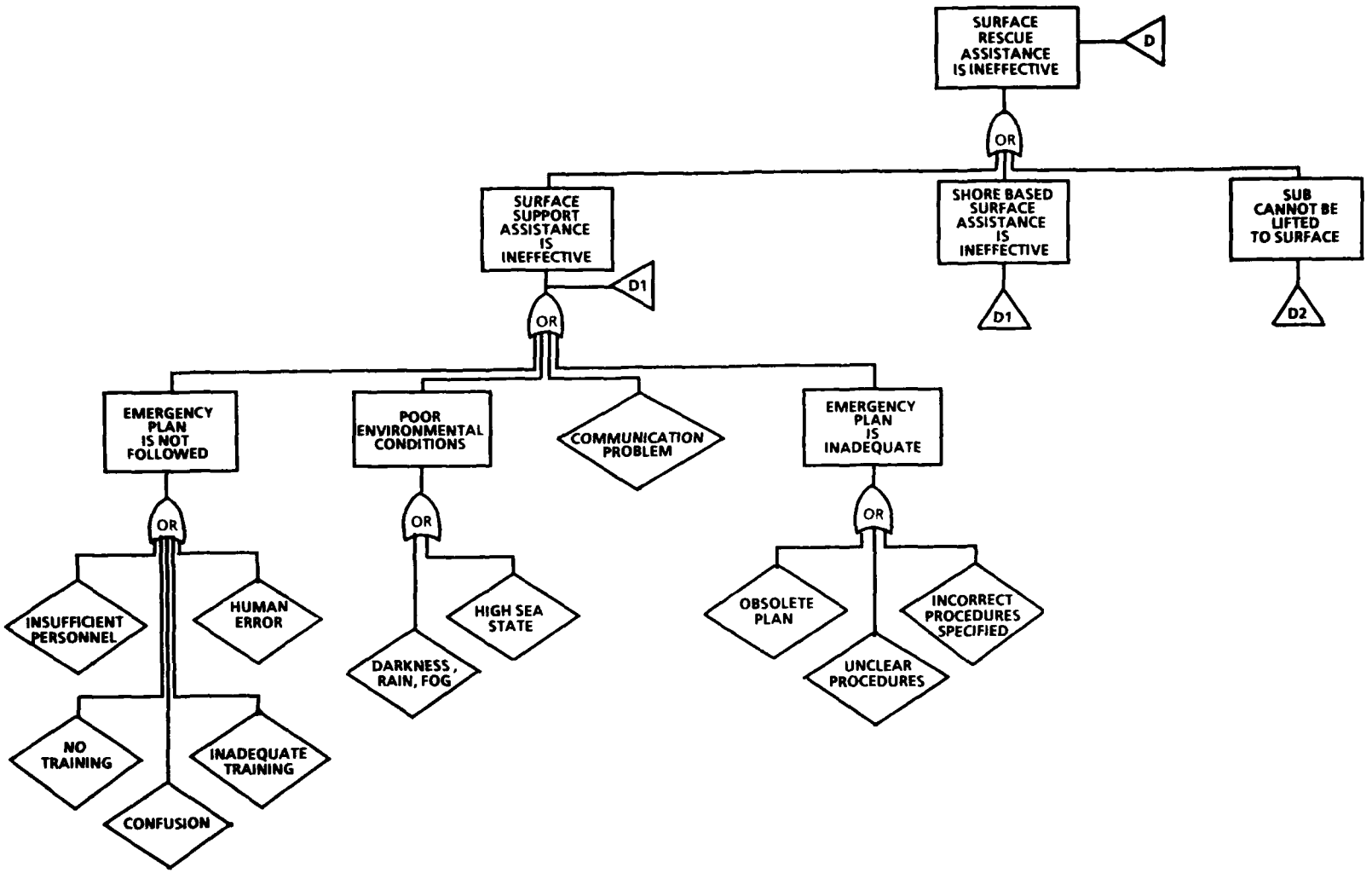

COLLISION OCCURS
OR
COLLISION BETWEEN SUB AND OTHER VESSEL
COLLISION BETWEEN SUB AND OBSTACLE
OR
OR
COLLISION OCCURS WHILE SUB IS ON SURFACE
SUB SURFACES UNDER SURFACE VESSEL
AGGRESSIVE MARINE LIFE
IMPACT ON SEA WALL
OR
OR
1
SUB IS UNWARE OF SURFACE VESSEL
SURFACE VESSEL DOES NOT SEE SUB
POOR VISIBILITY
CREW INACTION/ ACTION
OR
OR
1
SUB DOES NOT SEE SURFACE VESSEL
SUPPORT VESSEL CREW DOES NOT WARN SUB
MOVING AT HIGH SPEED
RAIN, FOG, ETC.
DARKNESS
1
OR
OR
DARKNESS
RAIN, FOG, ETC.
TURBID WATER
SUPPORT CREW UNAWARE
COMM. EQUIP. FAILURE

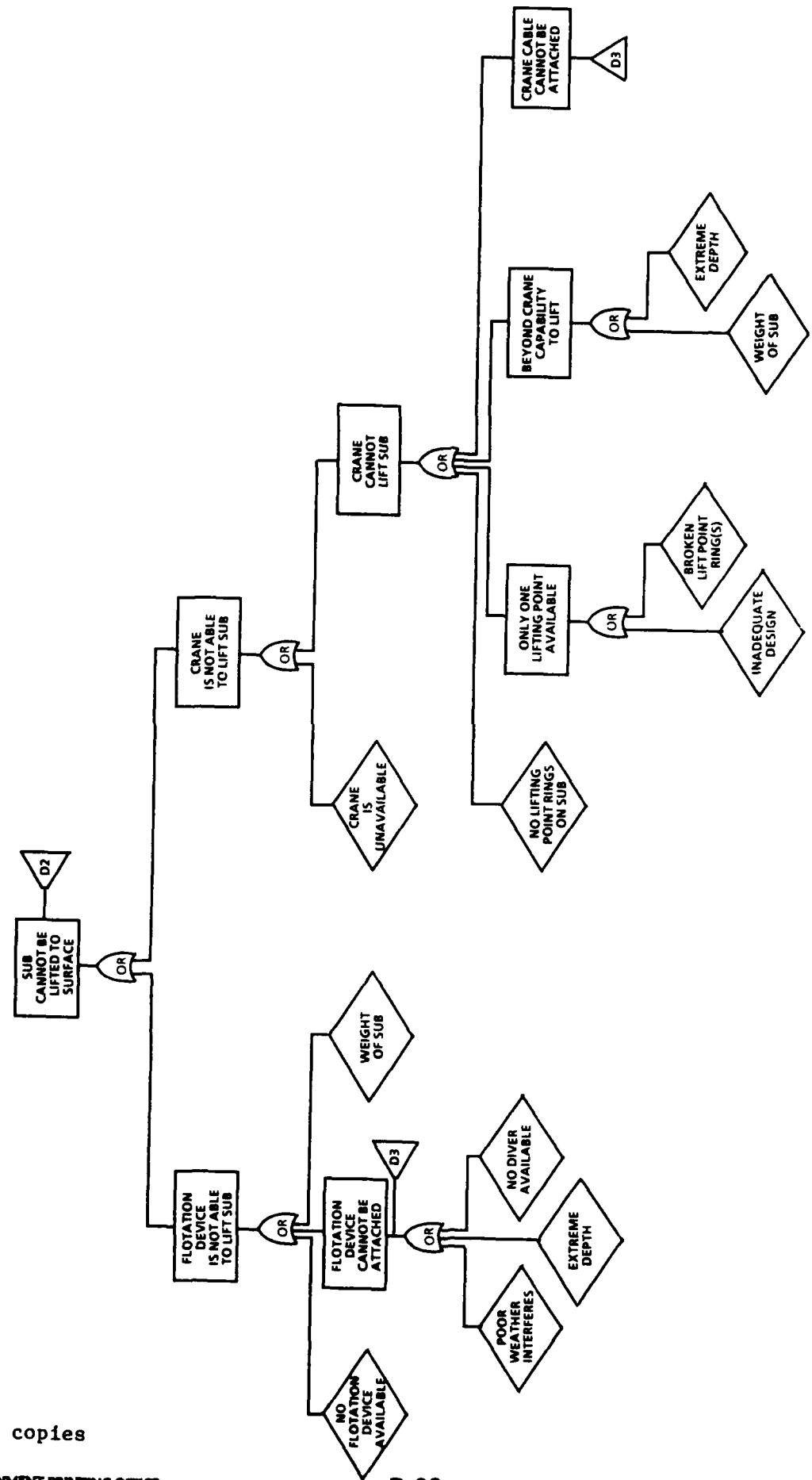

INDIVIDUAL DOES NOT ESCAPE FROM EMERGENCY CONDITIONS
OR
PASSENGER / CREW CANNOT LEAVE SUB
INDIVIDUAL DROWNS AFTER LEAVING SUB
OR
AND
!NDIVIDUAL CANNOT ESCAPE FROM SUB
INDIVIDUAL IS NOT RESCUED FROM SUB
INDIVIDUAL DOES NOT KNOW TO SWIM
INDIVIDUAL CANNOT GET OUT OF WATER
OR
OR
INDIVIDUAL DOES NOT TAKE TIMELY ACTION
EGRESS IS IMPOSSIBLE
ASSISTANCE IS UNAVAILABLE
ASSISTANCE IS UNABLE TO TAKE ACTION
A
OR
C
D
SUB DOES NOT SURFACE
HATCH CANNOT BE USED
OTHER EXITS DO NOT EXIST
B


INDIVIDUAL DOES NOT TAKE TIMELY ACTION
A
OR
INDIVIDUAL IS UNAWARE OF DANGER
A1
INDIVIDUAL DOES NOT KNOW WHAT TO DO
A1
INDIVIDUAL IS UNABLE TO TAKE ACTION
OR
INDIVIDUAL IS NOT INFORMED
A2
COMM. EQUIPMENT CANNOT BE USED
A3
INSTRUCTIONS ARE NOT UNDERSTOOD
A4
INDIVIDUAL IS UNCONSCIOUS
INDIVIDUAL PANICS
INDIVIDUAL REQUIRES ASSISTANCE
A5
HUMAN ERROR
CREW UNAWARE
CREW IS INJURED
CREW IS ILL
IMPACT INJURY
FIRE / SMOKE INJURY
NOT AVAILABLE
INOPERATIVE
INADEQUATE
WRONG LANGUAGE USED
INDIVIDUAL IS DEAF
COMMU. EQUIPMENT CANNOT BE USED
A3
IMPACT INJURY
AIR CONTAMINATION
OTHER INJURY
NOT TRAINED
INADEQUATE TRAINING
CONFUSION
INJURED INDIVIDUAL
INDIVIDUAL IS HANDICAPPED
ELDERLY INDIVIDUAL
OTHER DISABILITY
BLIND


HATCH CANNOT BE USED
B
OR
HATCH CANNOT BE OPENED
INSUFFICIENT TIME TO EXIT
HATCHES ARE NOT ACCESSIBLE
OR
HATCH LOCATON CANNOT BE IDENTIFIED
INDIVIDUAL DOES NOT KNOW TO OPEN
HATCHES ARE JAMMED
UNKNOWN CONTROL LOCATION
RAPID GROWTH OF FIRE / SMOKE
RAPID ENTRY OF WATER
HATCHES ARE BLOCKED
INDIVIDUAL MOBILITY IS LIMITED
HATCHES CANNOT BE REACHED
A1
B2
B3
A5
UNMARKED LOCATION
VISION IS LIMITED
B1
LOSS OF PRESSURE
MALFUNCTION
FIRE SPREAD/ HEAT BUILDUP
SMOKE GENERATION
PASSENGER CRUSH
IMPACT DAMAGE
NOT ENOUGH HATCHES
REMOTE LOCATION OF HATCH
WAY TO HATCH IS BLOCKED
LADDER CANNOT BE USED
NO EMERGENCY LIGHTS
POOR LIGHTING
SMOKE GENERATION
VANDALISM
IMPACT DAMAGE
JAMMED


SURFACE RESCUE ASSISTANCE DOES NOT RESPOND
C
OR
SHORE BASED ASSISTANCE DOES NOT RESPOND
SHORE BASED ASSISTANCE IS UNAVAILABLE
SURFACE SUPPORT CREW DOES NOT RESPOND
OR
ASSISTANCE IS NOT NOTIFIED
ASSISTANCE CANNOT REACH SUB DIVE SITE
UNDER REPAIR
NOT IN PORT
SUB CREW DOES NOT INFORM SURFACE
SUPPORT CREW CANNOT RESPOND
C1
SURFACE SUPPORT CREW UNAWARE OF EMERGENCY
SURFACE SUPPORT CREW DOES NOT NOTIFY SHORE ASSISTANCE
UNKNOWN LOCATION OF SUB
WEATHER
DIVER IS UNAVAILABLE
HUMAN ERROR
SURFACE COMM. EQUIP. FAILURE
SUB CREW DOES NOT INFORM SURFACE
COMM. EQUIP. FAILURE
HUMAN ERROR
NOT SPECIFIED IN EMERGENCY PLAN
C1
COMM. EQUIP. FAILURE
CREW INJURY
HUMAN ERROR


SURFACE RESCUE ASSISTANCE IS INEFFECTIVE
D
OR
SURFACE SUPPORT ASSISTANCE IS INEFFECTIVE
D1
OR
SHORE BASED SURFACE ASSISTANCE IS INEFFECTIVE
D1
SUB CANNOT BE LIFTED TO SURFACE
D2
EMERGENCY PLAN IS NOT FOLLOWED
OR
INSUFFICIENT PERSONNEL
HUMAN ERROR
NO TRAINING
INADEQUATE TRAINING
CONFUSION
POOR ENVIRONMENTAL CONDITIONS
OR
HIGH SEA STATE
DARKNESS, RAIN, FOG
COMMUNICATION PROBLEM
EMERGENCY PLAN IS INADEQUATE
OR
OBSOLETE PLAN
INCORRECT PROCEDURES SPECIFIED
UNCLEAR PROCEDURES



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